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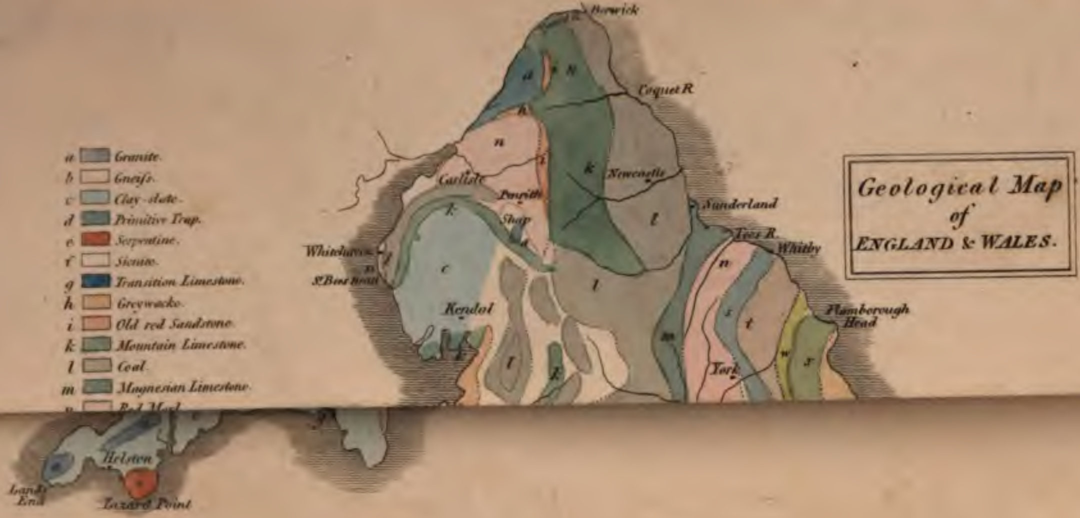

Geological Map of ENGLAND & WALES.

A

SELECTION OF FACTS

FROM THE BEST AUTHORITIES,

ARRANGED SO AS TO FORM AN OUTLINE OF THE

GEOLOGY

OF

ENGLAND AND WALES.

With a Map and Sections of the Strata.

BY WILLIAM PHILLIPS, M.G.S.
Author of 'Outlines of Mineralogy and Geology,' and of
'An Elementary Introduction to Mineralogy,' &c.

LONDON:
PRINTED AND SOLD BY WILLIAM PHILLIPS,
GEORGE-YARD, LOMBARD STREET.
1818.

INTRODUCTION.

This little volume, being almost entirely a compilation from works of acknowledged merit relating to the Geology of England and Wales, is not offered to the notice of the scientific Geologist. It is intended for the use of the beginner, in the hope that it may prove advantageous to him, as an introduction to the more comprehensive books from which the information it contains has been principally extracted, and as an incitement to the practical study of the geology of our own country.

While compiling the following pages, it did not escape recollection that it was my duty to set before the beginner, a representation of "Facts", in a fair and candid manner; that it would be an advantage to disencumber them as much as possible of theory; and especially, that the selection ought not to be biassed by any theoretical views of my own. In the yet infant state of our knowledge of the strata of England, and particularly of Wales, it will scarcely be denied that the student is more likely to reap benefit from a simple detail of well authenticated facts, than from the most able attempt to connect them theoretically.

Imperfect as our knowledge of the geology of our own country certainly is, it is nevertheless astonishing that so great progress in exploring it should have been made in a very short time: for it can hardly be said to have received general attention more than ten or twelve years. It is true that a countryman of our own, the Rev. J. Mitchell, in a paper on the subject of volcanoes, printed in the Transactions of the Royal Society for the year 1760, made some remarks on the regular stratification of the earth, which, considering how little was then known of Geology, have since been proved to be singularly correct. Among other observations, he says that, 'as mountainous countries are generally formed out of the lower strata, so the more level countries are generally formed out of the upper strata of the earth.'

Whether the remarks of that gentleman arose from a partial acquaintance with the regular stratification of England is uncertain; nor does it appear that inquiry was awakened by them. What is at present known, is in great measure to be ascribed to the indefatigable researches of one observer now living; who, during at least twenty years, has visited and revisited the greater part of England; and who, with an industry of which we can scarcely find a parallel, employed himself, on all occasions, in noting the peculiar facts exposed to his research, until at length he was enabled to form them into one grand outline for the information and benefit of the community. It will at once be understood that I refer to W. Smith, author of a "Map of the Strata of England and Wales;" in regard to whom, two circumstances at least are not less remarkable than honourable. The first, that during the earlier part of his career, he was in great measure, if not altogether unacquainted with any geological theories then existing relative to regular stratification; the second, that "he was the first who noticed, that certain fossils are peculiar to, and are only found in, particular strata; and first ascertained the constancy in the order of superposition, and the continuity in the strata of our island."*

Not only is his Map of the strata of England, when viewed as resulting from the labours of one man, a production which it is impossible not to view with admiration; but also in a geological point of view it is highly important, inasmuch as it has been the principal means of teaching us the interesting fact, that *England is a regularly stratified country:* and the experience of every day tends to shew, that *there is an order belonging to its strata.*

This Map therefore is extremely instructive, even though we should be compelled to acknowledge that it is not in every part equally accurate in detail: but as the large and expensive scale on which it is executed, forbids its being generally within the reach of the young Geologist, I was induced, by permission of its author, to take it as the basis of one on a very small scale, and to annex it, together with a few short and very general remarks on the stratification of England and Wales, as an appendix to the second edition of my 'Outline of Mineralogy and Geology.' While contemplating a third edition of that little work, it occurred to me, that if those few and general remarks could advantageously be increased, it would tend to forward the science: and knowing from experience the value of "Facts," I determined, although it must be acknowledged that the occupation is an humble one, to make a "selection of the facts" already made known, and to publish them for the use of the student, I might rather say of the beginner, in a separate volume; being unwilling to increase too greatly the size of the "Outlines," or to render it impossible for the purchaser to obtain the one without the other.

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* Geol. Trans. vol. i. p. 325.

The Map placed opposite to the title page, small as it is, affords a general view of the nature and position of the strata of England; it is impossible that one on so very small a scale should be accurate in detail, but it serves to shew that the western side of the kingdom consists of those rocks which are esteemed to be of the oldest formation; that the middle district, in which the strata more evidently run, generally speaking, north-east and south-west, consists of the older secondary rocks; and that the eastern parts, consisting chiefly of chalk and of strata reposing upon it, are of the newer secondary; but a very large proportion of the immediate surface of the country, especially of the lower tracts, consists of alluvial matter.

The greatest elevations are found in Wales and the North of England. The rugged outline, and occasionally the precipitous summits of these, are to the observer indications of their being of the earliest formation; while the smooth and rounded undulation of the hills in the central and eastern parts of the kingdom, bespeaks their newer formation, even though not a speck should appear, divested of herbage. The outline of a country is commonly a better means of judging of the comparative ages of the rocks composing it, than their elevations. The granite range of Cornwall no where attains so great a height as many mountains in Wales and the northern parts of England, though commonly esteemed to be of earlier formation. The granite of the west of

England does not exceed 1360 feet above the sea; while Snowdon, whose rugged peaks consist chiefly of rocks of the trap formation, attains the height of 3456 feet.

Regular, numerous, and varied as are the strata of England, it is nevertheless possible that a traveller, whose attention has in no degree been turned to geological objects and pursuits, should pass over a long tract of country consisting of very different rocks, without noticing their difference. The sod is so continuous in many districts, and the alluvial matter so deep, that superficial observers have little chance of remarking a change in the nature of the sub-stratum. As the artist views every object that presents itself in a manner which bespeaks him mindful of his art; so the geologist, as he passes along, regards every opening beneath the surface, every quarry, as yielding him some information in his favorite pursuit; and the experienced geologist, viewing nature on a broader scale, can with a sort of instinctive readiness discern, even at a considerable distance, any remarkable change of the sub-stratum, by remarking the character and outline of surrounding elevations.

An inspection of the Map will evince that the strata of which our country consists, vary greatly in dimension as well as in regularity. The same stratum in one place may be some miles in extent at the surface, or rather, immediately beneath the soil or alluvium composing it; becoming, perhaps at no great distance, diminished and narrowed to a very small compass, or even entirely lost; so that the two rocks which before bounded it one on each side, now immediately repose the one upon the other. Again perhaps it re-appears and again is lost. The appearance of a stratum at the surface is termed its *outgoing*, *basselling*, or *cropping out*. Its direction beneath the surface is termed its *dip:* when a stratum, or rock, is in its natural position, it is said to be *in situ.*

The strata of which our island is composed, have not all hitherto received equal attention. Nor perhaps is it to be expected that they should; for in regard to some of them, there are difficulties to be surmounted beyond the mere opportunity of tracing a stratum, beyond ordinary acquirement in geological knowledge. I allude to the older formations, as they are commonly termed; which, *not being homogeneous rocks*, but compounds, consisting of *several minerals* frequently, and indeed most commonly, in a state of minute aggregation, demand for their investigation an intimate acquaintance with simple minerals. Upon the subject of this acquirement, as connected with geological investigation, I shall attempt for a short time to detain the reader.

It is very possible to become acquainted in the closet with all the arguments of the opposite theories of *fire* and *water;* with Geology generally, and with that of our own country in particular, in so far as it is commonly known, by due attention to the works which treat on these subjects. Without being able to distinguish the most common rocks from each other, such information may be attained of the character and relative positions of the several formations of our island, as to constitute what may be termed a good *talking Geologist;* and this without having seen much, if any thing—without having become practically acquainted with one of its numerous strata. But we may proceed. It is very possible that in addition to his studies in the closet, a real lover of the science may be practically acquainted with almost every formation between the newest alluvium and mountain limestone, and therefore well versed in whatever relates to this part of the geology of our island; but even though he should have proceeded thus far, it may be said that he will be at least as remote from the character of a Geologist, as a child would be from the capability of reading, who having his alphabet by heart, is acquainted by sight with only half its characters. He would be what may be termed, *a Geologist on the broad scale*, unless he shall also be enabled, *by a previous knowledge of simple minerals*, to proceed west of the mountain limestone. Without this knowledge, he would find himself, when travelling in the western or northern counties of England, or especially in Wales, in a country abounding in rocks, almost as unintelligible to him, as though he were a stranger to the science. Without an intimate acquaintance with simple minerals generally, he would feel little interest in the midst of by far the most interesting tracts of our island.

Mineralogy, I repeat, is essential to a Geologist; it is the very alphabet to Geology. I repeat also that it is not requisite to become acquainted with all the niceties connected with mineralogical research, nor with every mineral substance.* Some, not to say many minerals, are found only in veins, never as the components of rocks: but unless the Geologist begin by the study of Mineralogy, to take an example from the component minerals of those which are commonly considered to be the oldest rocks, he will occasionaly be in danger of mistaking carbonate of lime, and a variety of other minerals, for felspar; talc for mica; and calcareous spar in some instances for quartz.

These observations may perhaps be thought superfluous by some, as tending only to insist unnecessarily on that which is acknowledged to be true. That it is granted by many, I am fully aware; but it must have been observed that there is a fashion in science, as in the common arts of life; and if I mistake not, Geology is now in fashion. And therefore, having been personally acquainted with several, and by report with far more numerous instances, in which it has been thought most eligible, as being the easiest road to the acquirement of Geology, altogether to omit the requisite previous acquaintance with simple minerals, I am anxious, for the honour of the science, and the ultimate satisfaction of the student, to prove to him that the study of mineralogy is an essential preliminary step, and to warn him against falling into the too fashionable error of neglecting it.

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* See my Elementary Introduction to Mineralogy, p. v.

It is frequently difficult, sometimes impossible, even for the most scientific mineralogist, accurately to determine the designation of a compound rock, when presented only with a hand specimen. The minuteness of aggregation, and the frequent transitions of one compound into others with which it is allied, often renders it extremely difficult for the most experienced to determine the class to which a rock belongs, even when seen *in situ*, which is the most favourable circumstance under which it can be observed. To these obstacles in part may be ascribed, the very slight information that has hitherto been given of some of our tracts of country consisting of rocks which are commonly termed primitive; and why, in some cases, we know nothing more of them than that they exist. Of the secondary formations we have generally a better and more detailed account, being more readily recognized, not only by the organic remains they contain, but also because they are less liable to those transitions just spoken of, and they are more commonly homogeneous. Still, however, much is to be learned respecting many of the secondary formations; little or nothing has been made public respecting some of them, amongst which it may be remarked that, of the oolite, the outcrop of which occupies a very large tract traversing England from the Humber, and perhaps even higher north, quite to the coast of Dorsetshire, and which consists of very numerons beds of very different natures, no details have been published. We must, however, here recollect that research is proceeding with a rapidity truly astonishing, and considering how short the time is since it began, it excites admiration that so much has been done, rather than disappointment that so much more yet remains uninvestigated.

It is worthy of note, that Dr. Berger, who had explored many, if not most parts of the European Continent previously to his visit to this country, observes that, 'If we take a comprehensive view *of the southern counties of England, from the coast of Kent to the Land's End*, we may safely assert that there are few countries, which, within such limits, can boast *of so varied and regular a succession of rocks; from those which are reckoned by most geologists to be of the latest formation, to those which are of the oldest.*'*

On referring to the map, it will be at once observable, that the eastern side of England consists of the newest rocks. In proceeding westward therefore, we should pass over the outcrop of formations still older than the preceding: and we should find that the western side of England, and a very large proportion of Wales, consist of those rocks which are commonly considered as being of primitive formation. When therefore we reflect on this, and when also we recollect that the researches of geologists prove that the older strata pass beneath the newer, we should theoretically decide that the older rocks on the west must *dip* under the surface, passing away beneath the newer formations on the east of them; and consequently that all the numerous succeeding strata must incline, generally speaking, in the same direction. This proves to be the fact; and it has been observed that the angle at which the strata dip, increases as we proceed westward.

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* Geol. Trans. vol. i. p. 267.

Figure 2, of plate 2, will therefore represent a section of the country over which a traveller would pass, from beyond London on the east to the Land's End in Cornwall. It also shews the general dip of each stratum, as well as the interesting fact, that the dip of each forms a greater angle with the horizon in proceeding westward; those on the east most nearly assuming that direction which determined Werner to give to the newer secondary rocks, the term of Flœtz, or Flat Rocks.

Such, then, is the remarkable regularity of the strata of the southern counties of England. It will however be seen that, in some of the formations which are best known, as having been most investigated, there are occasional deviations from this regularity; but it has generally been found that, where these have been noticed, they have been deviations in appearance, rather than in reality. The most scrupulous investigation of a considerable proportion of our strata assure us of the fact, that *order in regard to deposition is almost every where prevalent, and that this order is never inverted.* I quote the following interesting remarks from the first volume of the Transactions of the Geological Society, as being illustrative of this assertion.

'Chemical analysis has been called in to the aid of the naturalist, in order to account for the perfect state of preservation observable in remains organized with the most exquisite delicacy, and which there is every reason for supposing to have been readily decomposable in their recent state. From this investigation we learn the manner in which these memorials of the old world, so interesting and so frail, have been preserved. Some have been impregnated with calcareous matter, others with siliceous, and others with iron or copper pyrites. But these facts, however important and interesting, cannot, when considered by themselves, add much to our knowledge respecting the formation and structure of the earth. To derive any information of consequence from them, on these subjects, it is necessary that their examination should be connected with that of the several strata in which they are found.

'Already have these examinations, thus carried on, taught us the following instructive facts.

'That exactly similar fossils are found in distant parts of the same stratum, not only where it traverses this island, but where it appears again on the opposite coast: that, in strata of considerable comparative depth, fossils are found, which are not discovered in any of the superincumbent beds: that some fossils, which abound in the lower, are found in diminishing numbers through several of the superincumbent, and are entirely wanting in the uppermost strata: that some fossils, occurring in considerable numbers in one stratum, become very rare in the adjacent portion of the next superincumbent stratum, and afterwards are lost: that fossils of one particular genus, which exist abundantly in the lower strata, and occur in several of the superincumbent ones, are not found in the three highest strata; whilst one species of that genus, but which has not been found in a fossil state, exists in our present seas: and lastly, that most of the remains which are abundant in the superior strata, are not all found in the lower. These general facts lead us to hope, that geology may derive considerable assistance from an examination of fossils, made in connexion with that of the strata to which they belong.' *

Keeping in view the important fact, that the strata of the southern counties dip towards the east (See pl. 2, fig. 2), we, who reside on the eastern side of England, and on deposites of the newest formation, might amuse ourselves with speculating on the distance which any one of the more ancient strata, which in the map and section are seen cropping out in some of the western counties, dips beneath our feet. This can only be done as a matter of curiosity; for we cannot even hope to approach the truth, because of the uncertainty whether the numerous strata to the west of us do, or do not actually continue to dip towards the east, for any considerable distance beneath the surface. Even if we were to assume this to be the fact, for the sake of amusing ourselves with a calculation of some sort, we should still be at a loss as to the probable thickness of the several strata. Coal is one of the most important deposites, and therefore claims our consideration in as great, if not in a greater degree, than any other. On looking at the map we shall observe that the nearest

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* Geol. Trans. vol. i. p. 324 & seq.

place to London at which coal is found, is in the neighbourhood of Bristol, near to which it dips towards the east, beneath the red marle, and above the mountain limestone. It is thus represented in the section, Fig. 3, of Pl. 2; by which we may observe, that there are very many formations lying between the London clay and the coal, which are believed all to dip together towards the east. And when we recollect that the outgoing of the nearest coal to London, is upwards of 100 miles from it; that the wells there pass from 150 to 300 feet through the London clay before the sand which lies upon the chalk is arrived at, and from which the water springs; if again we consider that between the sand and the coal, the numerous strata extend *on the surface* over a tract of country about 40 miles in length from east to west, as from Hungerford to Bristol; and if moreover we imagine all these strata to be compressed *beneath the sand which covers the chalk*, into one twentieth part of what their outgoings occupy on the surface; we should even then be compelled to suppose that the strata of coal are more than two miles beneath the bottom of the London clay. How near the truth this calculation may be, or whether the coal and all the strata intervening between it and the chalk pass away beneath our feet, we have no reasonable ground for concluding; but we are acquainted with the important geological facts, that the dip of the older rocks beneath the surface is much more highly inclined than that of the rocks of a middle age, and that the dip of the newer rocks becomes less and less inclined, until we arrive at the newest, which lies nearly flat. The difference of inclination in rocks of different ages, it will be recollected, caused Werner to designate the more recent of them by the name of flœtz or flat rocks, on occount of their nearly flat position. We are moreover acquainted with the fact, that the dip of the formations on the east of the lias, all of which are newer than it, is very inconsiderable; so that the allowance we have made for the thickness of the strata, between the bottom of the London clay and the surface of the coal, may far exceed the truth, even though our allowance does not exceed one-twentieth of the distance which the outgoings of these strata occupy on the surface. The coal near Bristol dips towards the east, to use the miners' phrase, 3 feet in 6; in other words, if the stratum of coal be followed down from its outgoing at the surface for 6 feet, a perpendicular line let down to that point from the surface would be found to be 3 feet in length.

With regard to the general level of the country in England above the sea, it is difficult to form a precise notion; it may however be remarked that the Ashby de la Zouch canal which runs nearly due south from that place chiefly over the red marle, is 274 feet above the level of the sea at high water mark, and takes its course for 70 miles without a single lock.

It is also worthy of remark that the vallies which take their course *along the direction of the strata* at the surface, are longer, more open, and less rugged than *those which traverse the strata*, the smaller extent and more rugged surfaces of which appear to denote, that at least some of these are not attributable to the same cause as the former, namely, to that of regular deposition; but to a disruption of the coutinuity of the strata on the surface by various, remote, and inexplicable causes.

The space which is without colour, forming, according to the geographical divisions of England, the northern parts of Cambridgeshire and the eastern parts of Lincolnshire, and bounded on the north and east by *the Wash*, can scarcely be said to form a part of the geological features of England. With very little exception, it consists of fens and marshes: many thousand acres of it have been retrieved from the sea, which it is well known has at different periods retired from particular parts of our coasts, and again returned. Of this there is a remarkable instance on the coast of Kent. It is known that the sea once covered, and perhaps at no very distant period, the extensive tract of flat land known by the name of Romney marsh, now affording pasturage for many thousands of cattle, whose security depends on the stability of a barrier of earth 14 miles long, called Dimchurch wall, which has been thrown up, and is kept in constant repair to oppose the progress of the sea; the surface of which, at high water, is many feet above that of Romney marsh. The eastern parts of Lincolnshire and the northern parts of Cambridgeshire, (although a large part of them has of late been regained from the sea and is now cultivated), were formerly, if not in a state of cultivation, yet considerably above high-water mark, as is evinced by the numerous remains abounding therein. The trunks and roots of large trees are very frequently discovered; and it is not long since the trunk of an oak, 90 feet long, was found buried in the marshes on the coast of Lincolnshire.

Dr. Kidd is of opinion that "we may at least be convinced that the science of geology is at present so completely in its infancy, as to render hopeless any attempt at successful generalization, and may therefore be induced to persevere with patience in the accumulation of usesul facts.*" The perseverance here recommended is indeed most essential to the science. The attention that has now for some years been given to geological research, has consigned almost to oblivion many a splendid theory, and has tended in a most important degree to damp that ardour for theorizing which once prevailed so greatly: and though it is impossible to withhold a smile at the many amusing and crude conceptions which once dazzled the world, and equally so not to feel gratified that philosophy now takes a humbler flight, we must not undervalue theory, even though investigation has not hitherto proceeded to its utmost limit; for when grounded upon observation, theory is extremely useful and equally reasonable. Remote from perfection as is our present knowledge of the geology of England, and it certainly is very remote, it is impossible to give even a short attention to the little map at the beginning of this volume, which is a study of itself for the beginner, without feeling assured that much is already known of the *general geological history of our country*: that is to say, the western side is found to be almost wholly constituted of rocks, which, as they contain no organic remains, are generally esteemed to be of the oldest formation, and the eastern side of the newest, while the outcrop of those which both from their nature and the organic remains they enclose, are esteemed to be of a middle age, occupies the central parts.

But in forming these conclusions, it may be said that theory is involved. It is, in the estimation of some

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* 'Geological Essay on the imperfect Evidence in support of a Theory of the Earth,' &c. p. 269.

Geologists, altogether theoretical to conclude that certain rocks, which contain no organic remains, and which underlie those which do contain them, are therefore of older formation. By such, they are believed to be newer than many which they support. I am not about to enter into the merits of this question.* It is noticed here only to shew that, although order of some sort is almost universally agreed to prevail, we cannot adopt the ordinary language of the science in its more intelligible and reasonable form, without theorizing in some degree. In this view of the subject, we theorize in assigning to rocks a classification. Hence their common division into primitive, secondary and alluvial, as regards the first, if not the second class; is to be considered as matter of theory.

In the following pages I have abstained from any classification, and have adhered as closely as possible to mere geological fact, as it relates to the general characters, and *actual relative position of the strata* composing England and Wales; leaving, therefore, as much as possible, all theory out of the question. But I have great pleasure in being permitted to add to the facts of which this little volume is composed, a very important and useful tabular view of our rocks, entitled the "Order of Superposition of Strata in the British islands, by the Rev. W. Buckland, Professor of Mineralogy in the University of Oxford." This document I have been allowed to insert by the liberality of the author, whose indefatigable research is well known: and who, solicitous for the progress and dissemination of the science, had prepared it for the illustration of his lectures on Geology. This classification is necessarily theoretical in part, and professes to shew the general agreement of the British strata, with the order adopted by the Wernerian School. It cannot fail to interest and instruct the student, as exhibiting at one view the great series of our rocks, and as containing many localities which have not I believe been made public in any other form. I beg therefore to recommend it to the diligent attention of the student.

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* See my 'Outlines of Mineralogy and Geology,' &c. 3d edition, page 195; and seq.

It remains to say a few words on the subject of the sources whence have been extracted the "Facts" included in this volume. It has been my intention to exhibit in the smallest compass, a detail of well founded observations, adequate in some sort to instruct the beginner, to induce his attention to the geology of our country, wherever he may happen to travel; and to convince him that every opening beneath the surface, possesses some degree of interest for the practical geologist. It cannot be expected that so slight an outline should satisfy him. Many details included in the valuable records, whence these facts have been taken, are necessarily omitted; and much might have been added from other sources, but it was my wish to make rather a "Selection," than a collection. A very large proportion has been extracted from the highly interesting and valuable volumes of the Transactions of the Geological Society; but these extracts often fall short of their proper and original interest, since they are unaccompanied by the splendid and illustrative plates belonging to those volumes: whatever is unintelligible without their aid, has necessarily been omitted.

W. P.

April, 1818.

Works from which the following ‘Selection’ has chiefly been made.

	Letters, &c. of reference.
Memoir on a Map of the Strata of England, by W. Smith	S.
Stratigraphical System of organized Fossils, by W. Smith	Smith.
Transactions of the Geological Society	G. T.
Transactions of the Royal Society	P. T.
Journal of Science and the Arts, edited at the Royal Institution	R.I.J.
The Annals of Philosophy, &c. by T. Thompson.	Aun.
The Philosophical Magazine	P.M.
A General View of Derbyshire, &c. by John Farey, sen. Vol. i.	F.
The Mineralogy of Derbyshire, by John Mawe.	M.
A Geological Essay on the imperfect evidence in support of a Theory of the Earth, &c. by J. Kidd, M. D. Professor of Chemistry in the University of Oxford	K.
Letters by T. Webster to Sir H. Englefield, Bart. included in his Description of the I. of Wight.	W.
Elements of Geognosy, by R. Jameson	J.
Traité Elémentaire de Mineralogie, par A. J. M. Brochant	B.

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ALLUVIUM.

§ 1. WE begin with the newest deposite; with that which is found in almost every part of England, occasionally covering the summits of the more elevated tracts, but more often resting on their sides, and still more commonly forming the surface of low lands, sometimes to a considerable depth, and effectually hiding from observation, the nature of the stratum on which it is deposited. Alluvium occurs beneath the vegetable soil or mould, and consists of the ruin, or debris, of the neighbouring rocks, or even of very distant strata, fragments of which are often enclosed in the gravel, or sand or loam, or mud, or silt of which this deposition consists. Some of them enclose the bones of animals, not in a mineralized state, and occasionally shells, of which it is remarkable that some have been found more nearly approaching those now existing in the sea, than such as occur even in the newest of the regular strata. The name of this deposite is descriptive of its undoubted origin: Alluvies, in the Latin, signifies a land-flood. This term, however, might seem to confine the cause that has produced ruin of so great extent to the ancient agency of almost universal floods. But it is certain that there exist accumulations of some of the substances already named, which are not of ancient date, but that result from causes even now operating. Such are the consequences of mountain torrents and of rivers. These, carrying down the portions of rocks detached by the action of the atmosphere, or of water, sometimes leave accumulations of detritus which tend materially to alter the features of a country: and by reasoning on the smaller operations of nature, we are sometimes enabled to form an estimate of those which are on a larger scale. While the earth is thus suffering a gradual decay, and its ruin is eventually carried by the rivers into the ocean, a spoliation is also in some places going forward on the shore by the action of the waves;* which on the contrary, in others, are throwing upon it sands, that, accumulating and hardening, become in process of time a substantial barrier to the sea.

Our object is chiefly the alluvium which overlies the strata of England. It may not, however, be amiss to say, that on some of its boundaries, and particularly on some parts of the rocky shore of the northern coast of Cornwall, the ocean has continued to throw up, from time immemorial, large quantities of fine sand, considerably calcareous in its nature, which has been observed to be here and there hardening into the consistence of a rock.†

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* On the coast of Somersetshire bordering the Bristol Channel, and for some distance westward of the river Parret, the remains of a forest is visible considerably below the level of the sea: it is now only to be seen at low water. A description of it is given in the 3d vol. of the Geological Transactions, p. 380. Another on the coast of Lincolnshire, is described in the Philosophical Transactions for 1799.

† On this subject we may hope to find an interesting memoir in the volume of Transactions of the Geological Society of Cornwall, which is about to be published.

§ 2. In illustration of the effects ascribed to rivers, it is perhaps impossible to quote any facts more apposite than the following, which relate to the banks of our own river, the Thames; they are extracted from the 4th volume of the Transactions of the Geological Society, where they form an appendix to a valuable communication by the Rev. W. Buckland, on the Plastic Clay formation.

It is well known that at this time the waters of the Thames, from London to the sea, are upheld by dykes or sea walls. Within these dykes the river by its daily sediment of mud has so raised its bed, that even in ordinary tides the water is above the level of the meadows, as far up as Woolwich and the Isle of Dogs. This elevation of its bed is precisely analagous to what has happened near the mouths of the Po, the Rhine, and other large rivers, which have been upheld for many centuries by embankments. The following facts tend to illustrate the process that was going on before the period at which these embankments were made.

In the account given by Capt. J. Perry, about 100 years ago, of the stopping of the breach made in the sea-wall at Dagenham, about twelve miles below London, that able engineer particularly describes what he calls moor log. This, he says, was composed of vegetable matter heaped together, but chiefly of brushwood, among which there appeared to be a considerable quantity of hazel trees; hazel nuts were also found in the mass, but were easily crushed, the kernel being entirely perished. There were also trunks of other trees, of which the yews were the least decayed; some of them measuring 15 or 16 inches in diameter. There were also willows two feet and upwards in diameter; they retained a whitish colour like touchwood, and were softer than the adjacent earth or moor log. The moor log appeared at about three or four feet under the marsh ground, and differed in thickness at different parts; at Deptford it was six feet thick; at Woolwich Reach, opposite the ballast wharf, it was between seven and eight feet thick; its thickness as well as its breadth gradually increasing down the river. Beneath the moor log was a stratum of blue clay, and under this, gravel and sand. Stags horns were likewise found in different places, a little above the vein of moor log.

Mr. Derham's account of the Dagenham marsh land (Phil. Trans. 1710, p. 478), affords the following particulars in addition to those given by Capt. Perry.

The stumps and roots of many trees were found in the same posture in which they grew, situated in a soil consisting of a black oozy earth, full of the roots of reeds; the tops of these stumps were so worn that it could not be ascertained whether the bodies had been cut off by the ax, or broken by natural violence. The bodies themselves lay horizontally on the surface of the oozy earth, in confusion, but a northerly direction seemed most prevalent. They appeared almost all of them to have been alder, though at first they were supposed to be yew. Over the trees lay a covering of grey mould, of the same nature with the sediment of the Thames at this day, varying in thickness from seven to twelve feet. Mr. Derham mentions the name of the following places in which he noticed traces of this subterranean forest. Dagenham, Havering, Rainham, Wennington, Purfleet, West Thorrock.

It happened a few years ago that in cutting the canal and basins in the Isle of Dogs, a subterranean forest containing hazel nuts, with hazel and other trees, was discovered to lie under the bed of indurated mud, that forms the surface of that peninsula.

These data throw much light on the natural operations that were going on, between the period of the last retreat of the diluvian waters, and that at which sea walls began to be erected against the rising waters of the Thames. The substratum of clay and gravel mentioned by Capt. Perry, formed the first surface of the valley uncovered by mud or water, and lying at a small elevation above the then existing high water level of the river. The sediments of the river gradually raised its bed, and caused its waters to spread laterally over the adjacent low lands; first converting to marsh by inundations at high tides, and at length completely burying, by its daily sediment of mud, those tracts which in the early periods of the rise of the bed of Thames, had been quite dry and covered with extensive forests. The horns of stags that inhabited them lie on the surface of the moor log, which appears to be the wreck of these ancient forests, first converted to swamps as the water began to reach their level, at length wholly destroyed by the constant inundation of the ground on which they grew, and still affording evidence of their position and extent, in the roots and trunks that lie buried on the surface and in the mass of the moor log, and over which a bed of mud has subsequently been deposited by those gradually rising waters which caused the destruction of the forest. (G. T. vol. iv. p. 302—304.)

§ 3. The immense beds of loam and of gravel found every where beneath and around London, and especially on its northern side, are esteemed to be alluvial. London itself was built from the surrounding quarries of loam or brick earth, which yet are far from exhausted, and almost every part of it north of the Thames stands on a bed of gravel. Gravel also prevails almost every where around it, sometimes being above, sometimes beneath the brick earth. With this gravel almost all the great avenues to the city have been long repaired, and annually require repeated coatings of it. It may serve to convey some idea of the enormous quantity yet found in its neighbourhood to state, that on the first eleven miles from London, of one of the great northern roads, 22,000 cart-loads, each drawn by 3 horses, were consumed in repairs in 1817.

§ 4. Gravel is commonly considered to be Chalk flint, rounded by attrition, by the waves of an ocean which caused the destruction of some part of the upper chalk. This however, in the estimation of a geologist who has given much attention to the subject, does not appear to have been altogether the origin of our gravel beds in the neighbourhood of London. He finds that these pebbles sometimes differ greatly from any known chalk flint, and is inclined to consider them as having been once imbedded in a stratum which covered the London clay, and which was carried off in one of the many revolutions to which the earth has been subjected. (G. T. vol. ii. p. 238.) He says, (p. 239,) But when we see rolled pieces of granite, of quartz and other primitive rocks, occurring frequently in the alluvium of this part of the country, though so far removed from the places where these substances are in situ, we feel so assured of the extensive nature and violent action of the cause that has occasioned such destruction, that we need not wonder if many strata have been reduced to a state of impalpable division, and have been scattered over the surface, so that not a fragment remains entire; or have been deposited in the depths of the ocean, where they may have formed new combinations that may at some distant period be exposed to view, and afford matter for the contemplation of future generations.

§ 5. The organic remains enclosed in some of the alluvial beds, so plentiful around London, especially on the north, west, and east, merit particular notice.

In the deep and extensive beds of brick-earth, at Kingsland on the north, belonging to W. Hobson, Esq. were discovered not long since, two or three elephants tusks, which soon fell to pieces on exposure to the air.

Tusks of a similar kind were found a few years ago on the south of London, in the alluvium covering some beds of the plastic clay formation (§ 39.) in a garden opposite to the chalk pit, at the base of Loam Pit hill near Lewisham. These also soon fell to pieces on exposure. (G. T. vol. iv. p. 287.)

On the west of London, near Kew, the bones of the hippopotamus, of deer, and of the elephant were some years ago found, in calcareous beds, between a stratum of sandy gravel and the London clay. (G. T. vol. i. p. 340.)

On the east, have been found in an alluvial bed resting on the blue clay of the Isle of Sheppey, the remains of the elephant, stag, and hippopotamus; and at Walton in Essex, of the Irish fossil elk. (Parkinson's Org. Rem. vol. iii. p. 366.)

It is worthy of particular notice, that some of the beds of alluvial matter in Essex, contain fossil shells, some of which are in remarkable preservation. These shells are found mingled with sand and gravel, the whole forming a bed 20 or 30 feet thick, lying upon about 15 feet of blue clay, in the cliff at Walton Nase near Colchester. Similar shells are also found in Suffolk and great part of Norfolk; also through Essex, Middlesex, part of Kent and Surrey, and through Hertfordshire and also in Buckinghamshire. (G. T. vol. i. p. 330.) The greater part of these shells appear not to differ specifically, as far as their altered state will allow of determining, from the recent shells in the neighbouring seas. (G. T. vol. i. p. 332.) In this bed, and among the gravel and the shells, are frequently found fragments of fossil bones, which possess some striking peculiarities. They are seldom more than half an inch in thickness, two inches in width, and twelve in length; always having this flat form, and generally marked with small dents or depressions. Their colour, which is brown, light or dark, and sometimes inclining to a greenish tint, is evidently derived from an impregnation with iron. From this impregnation they have also received a great increase of weight and solidity; from having been rolled they have acquired considerable polish; and on being struck by any hard body, they give a shrill ringing sound. These fragments, washed out of the stratum in which they had been imbedded, are found on the beach at Walton, but occur in much greater quantities at Harwich. (G. T. vol. i. p. 335.)

§ 6. The Hertfordshire puddingstone consists of rolled or rounded pebbles imbedded in siliceous matter. These pebbles, in the estimation of geologists, are not rounded chalk flint, from which some of them differ altogether in colour and appearance. Whence they have been derived, or what is their geological place, is quite unknown, since neither the puddingstone, nor the pebbles of which it is in part composed, have been seen in situ. It now lies above the chalk: masses of it have been found that appear to have been rounded by attrition.

§ 7. On the cliff, near Compton Chine in the Isle of Wight, consisting of the ferruginous sand, and not far from where that and the other strata dip beneath the chalk, there is a bed of sand and gravel, 8 or 10 feet thick, beneath which lie numerous trunks of trees, some of them a foot or two in diameter: around them are found considerable quantities of small nuts, termed by the inhabitants Noah's nuts, resembling those of the hazel. Neither the wood nor the fruit is at all mineralized, but resemble the state of such substances when they have long lain in bogs and marshes. Among them have been found some phosphate of iron. It is worthy of notice, that no hazel whatever grows upon the island.

In the cliffs of Swanwich bay, on the coast of Dorsetshire, a similar deposite of fossil wood is found under the same circumstances. (W. 152.)

§ 8. From what has preceded, it appears to be very questionable whether the immense beds of gravel overlying the chalk, have been derived from its partial destruction, or from that of other beds which once lay above it. That the chalk strata of England have suffered greatly since their deposition, is most evident, not only from the immense quantities of loose angular flints, now lying in the hollows in their neighbourhood, but also from the large quantity of rounded pieces of chalk rubble, that are to be seen in some low situations; as for instance, in various places in the lowest parts of the long range of cliffs between Deal and Folkstone, and in the neighbourhood of Brighton (§ 54). But the high cliffs near Folkstone are covered by a red siliceous sand, commonly intermixed with clay, and frequently with mica, and enclosing masses of siliceous ironstone; a thick bed of flints in fragments lies at the bottom of it. The newer alluvium in the neighbourhood contains small fragments of flints and small rounded masses of chalk.

§ 9. On the summit of the Gogmagog hills, and on Harston hill, which are five miles apart, and which are estimated to rise 800 feet above the river at Cambridge, a deposite of gravel and loose stones, in horizontal layers, has lately been found, resting immediately on the chalk of those hills. This gravel differs in so many respects from the red ferruginous gravel found dispersed in patches over the gault (blue clay, or argillaceous marle,) in the subjacent flat, that it is considered to be a deposite of a different epoch. It contains numerous fragments of strata belonging to the oolite series, which occur in the neighbouring counties of Northampton and Rutland, surrounding Cambridge on the west and north-west. Pieces of basaltic rock are sometimes found, but these are not very common. These fragments are of all sizes, and worn down in different degrees. Some are pebbles entirely rounded; others have their edges merely blunted. Some are so tender, and so little incapable of resistance, that it is difficult to conceive how they have been transported without being entirely destroyed. The prevailing material of these masses of gravel is the pale blue or light grey variety of flint, with numerous traces of the alcyonium, or other similar bodies, in its substance.

Among this gravel on Harston hill, which is conical, and the sides of which are of naked grey chalk, were found pebbles weighing at least 8 ounces, bearing a close resemblance to the toadstone of Derbyshire; a large oyster belonging to the bed which underlies the coral rag, (one of the oolite series) and a large belemnite peculiar to the lower oolite. The outgoing of the toadstone, coral rag, and lower oolite is found only in a direction west of Cambridge; so that we are led to explain the accumulation of these alluvia by the agency of a powerful current flowing from west to east.* (G. T. vol. iii. p. 246.)

§ 10. The bed of gravel on which Oxford stands, and which extends, with occasional interruptions, to the distance of many miles in every direction, consists principally of fragments of coarse calcareous freestone and indurated portions of the iron-sand, of which most of the neighbouring hills are composed. It also contains fragments of flints, which may easily be referred to the chalk strata, situated at an average distance of from 12 to 14 miles. As these constituent parts occur severally in a proportion corresponding to the prevalence and vicinity of the strata from whence they have been derived, and as the bed of gravel itself occupies upon the whole the lowest level, there is no difficulty in admitting the probability that it was formed by means of water, which detached and wore down portions of the adjacent strata: but then, mixed with these fragments, the native beds of which are found in the immediate vicinity, are found pebbles of quartz and of various rocks, *none of which are known to occur within a distance of* 50 *miles;* and frequently both the size of these foreign fragments is larger, and their degree of hardness greater, than that of the native strata of the neighbourhood. In Bagley wood, and on a part of Wytham hill, which places are situated about two or three miles to the west of Oxford, there is a coarse gravel at a considerable height above the level of the surrounding country, many of the masses of which are each of several pounds weight; and are apparently derived from a district abounding in compact quartz rock, fine-grained micaceous gritstones, and obscurely defined compounds of hornblende and felspar; which last often assume a porphyritic character. This coarse gravel contains few, if any fragments of the neighbouring strata, and is altogether of a character so distinct from the gravel of the plain below, that it it difficult to suppose the two are parts of the same bed; but upon the whole it seems most probable that, however different in character, they must have been deposited by the operation of the same cause; for in other spots the constituents of both are found mixed together. (K. 151.)

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* From this, and probably from other deposites in similar situations, an opinion is I believe commonly entertained, that the last currents which swept the surface of our island flowed from the *west or north-west.* But it must be noticed that chalk flints are found in the alluvium near Oxford on the *western* side of the chalk range (§ 40); that pieces of flint are found in the quarry of Heavitree near Exeter (§ 147), which is considerably on the west of the western outcrop of the chalk; as is also Chudleigh in Devonshire, near which flint pebbles are scattered over the surface of the ground in great quantities. (G. T. vol. i. p. 103.)

Among the contents of the Oxford gravel are fragments of teeth and tusks and bones of elephants; horses teeth; bones of the hippopotamus (unless I am mistaken); and horns of a species of stag: and in this respect the gravel of Oxford corresponds with many similar depositions not only in England but in various parts of Europe. It is remarkable that the surfaces of these bones, &c. are sometimes in almost as complete a state of preservation as if they had never been moved from the spot where the animal died. Thus there is in the Ashmole museum a part of a stag's horn from this gravel, in which all the natural groves or channels, in which the blood vessels of the velvet of the horn formerly ran, remain uninjured; but the tip of a projecting branch near the root of the horn is worn quite smooth; as if (judging from the entire state of all the rest) the attrition had taken place during the life-time of the animal. (K. 152.)

In travelling from Oxford to any distant point, the character of the several gravel beds, occurring in the way, alters according to the nature of the surrounding country: thus as you approach the chalk range, fragments of the strata immediately subjacent to the chalk appear, and the proportion of flint increases; and immediately in the vicinity of, and on the chalk, the fragments of flints form more than nine-tenths of the whole mass. Or if pursuing other directions, you travel into the central parts of the kingdom, you meet with gravel made up principally of the *debris* of the strata prevalent in those parts. (K. 153.)

§ 11. The county of Nottingham, north of that town, and particularly the large tract called Sherwood Forest, is covered by an alluvium which at Nottingham and Mansfield, and at several intermediate points, consists wholly of sand, rounded quartz, and other siliceous

FRESHWATER FORMATIONS.

§ 15. For a description of these interesting formations, and I believe also for a knowledge of their existence in England, we are indebted to a communication to the Geological Society 'on the Freshwater formations of the Isle of Wight, with some observations on the strata over the chalk in the south-east part of England,' by Thomas Webster, M.G.S. inserted in the second volume of its Transactions.

§ 16. The position of these beds in the Isle of Wight is *above the chalk;* and it is said that in the chalk basin of London, there are occasional appearances of a freshwater formation. At Brentford, six miles from London, three beds were found overlying the blue London clay; upon it rests one, a few feet in thickness, of sand and gravel with water; upon it, a bed from one to nine feet thick, of calcareous loam; above which is a calcareous loam or common brick earth. These three beds contain a vast collection of the bones of elephants both African and Indian, of the hippopotamus, the horns and jaws of oxen, the horns of deer, and both *land and freshwater shells.* (G. T. vol. ii. p. 198.)

§ 17. There are some appearances also of a freshwater formation *below the chalk*, in the Isle of Purbeck (§ 70), consisting of a series of strata of shelly limestone, known by the name of the Purbeck stone, alternating with shale and marle. Some of the fossils of these strata strongly resemble freshwater shells; they appear to be cyclostoma, planorbis, &c. (G. T. vol. ii. p. 166.)

§ 18. It is to the Isle of Wight we must look for a knowledge of the freshwater formations above the chalk. Their characteristics are there perfect, and their position determinate: but in order that we may fully comprehend the nature of the evidence respecting these formations, it is necessary here to give some account of those with which they are connected in a very singular manner, and of those with which they alternate.

On the western side of the Isle of Wight, of which Alum Bay forms a part, there is a natural section of strata of several kinds, represented by fig. 1 of plate 2, which is a sketch of that accompanying the paper already alluded to, in the 2d volume of the Geological Transactions. On the southern extremity, the chalk is seen in nearly a vertical position, manifested by the position of the beds of flints; next to the chalk is a bed of chalk-marle belonging to the chalk formation (§ 45); on the north of these are many coloured and vertical strata of sands, marles, and clays, 1131 feet wide, belonging to the plastic clay formation (§ 33); and close to these is a stratum of blue clay, in every respect corresponding with the London clay (§ 28), except that here its position is nearly, if not quite vertical; whereas this clay, beneath and surrounding London, lies in nearly horizontal strata.

It will hereafter be seen (§ 48, 49) that there is good cause for concluding that the chalk and sands, together with this stratum of what is termed the London clay, were at some very remote period thrown down from their natural, and nearly horizontal position, to that in which they are now visible; and that *since their fall*, the nearly horizontal strata composing Headen hill, were deposited in their present position. Regarding their position, however, it may be advantageous to make a remark or two. We shall observe by fig. 1, pl. 2, that the northern line of separation of the London clay, from a stratum of yellowish sand, is not quite vertical; that the next bed of sand, forming the base of Headen hill, as far as it has been seen, is in a nearly horizontal position; to which the beds overlying it, more and more approach as their distance from the base increases. We shall also observe that the southern terminations of these beds are somewhat curved, or turned up; a circumstance reasonably attributed to their having been deposited, after the chalk and sands and blue clay had, most likely by some great subsidence of the strata on which they once stood, attained their present position.

Headen hill is about 400 feet high, being about twice the height of the vertical cliffs of Alum bay. In this hill only, do we see distinctly the alternation of marine and freshwater deposites. It is in a state of constant ruin, and by its section affords lofty cliffs, where its strata may be examined with the utmost facility. From the sandy stratum forming its base is taken a beautifully white sand, with which the manufactories of the best flint glass are supplied. This sand may be traced round the foot of the hill on the north side, and forms the bottom of Totland and Colwell bays, dipping gradually to the north. Over it lies a horizontal bed of black clay, about 35 feet thick, containing fossil shells, and sometimes selenite. (G. T. vol. ii. p. 184.)

§ 19. On the bed of blue clay rests the *Lower Freshwater Formation*, which therefore first claims attention. In Headen hill it consists of a series of beds of sandy calcareous and argillaceous marles, sometimes with more or less of a brownish coaly matter. Some of them appear to consist almost wholly of the fragments of freshwater shells, many of which however are sufficiently entire to ascertain their species. These are lymneus, planorbis, and cyclostoma, and perhaps the helix, and a bivalve resembling the freshwater mytilus. The beds are extremely irregular, and are not to be traced distinctly from each other for more than a few hundred yards, the remaining part being so hid by the mouldering slope, that the formation can only be observed in mass. It may be seen, however, extending round the north side of Headen into Totland bay, where it forms the upper part of the cliff; and at the point called Warden-ledge, it is found in a more uniform and indurated state. In Colwell bay, it dips to the north, is soon lost, and is not to be seen any more on that side of Yarmouth. A black coaly matter is sometimes interposed between this formation and the blue clay on which it rests. (G. T. vol. ii. p. 210.)

§ 20. The *Upper Marine Formation** is so termed because it is the uppermost stratum containing sea-shells. It lies upon the lower freshwater formation, which separates it from the lower marine formation.

In this hill this formation is about 36 feet thick, and appears about half way up the cliff. Its substance is chiefly marle of a light greenish colour, and the marine fossil shells it contains are so numerous that they may be gathered by handfuls, and are in general extremely perfect; few of them agree with those found in the London clay. It is separated from the upper freshwater formation by a bed of sand a few inches thick.

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* Extensive beds of marine shells enclosed in a red ferruginous sand, are found in Norfolk and Suffolk above the London clay. (§ 29.)

This stratum passes all round Totland and Colwell bays. In the latter there is a fissure called Bramble's Chine, the banks of which belong to this stratum; in them is a large bed of fossil oyster-shells, the greater part of which are locked into each other in the natural way. This stratum may also be traced all round the north side of the Isle of Wight, and is visible at Cowes, Ride, and Bembridge

The marine shells found in this stratum consist of the cerithium, many species, and of cyclas, cytherea, &c. (G. T. vol. ii. p. 215.) The shells of these genera, so numerous on the shore near Cowes, are derived from this formation. But the whole north shore of the island have been for ages in a state of constant ruin by the action of the sea and the sliding down of the soil. It is difficult therefore to find any part of the strata in their original situation; on this account freshwater and marine shells are frequently found together in confusion. (G. T. vol. ii. p. 213.)

§ 21. The *Upper Freshwater Formation*[*] is separated from the upper marine formation by a bed of sand six inches thick. It is 55 feet thick, and is in great measure composed of a yellowish white marle, that does not endure the frost, enclosing masses which are more indurated, and appear to contain a greater proportion of calcareous matter. This stone is durable, and is employed for building.

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[*] Without indulging improperly that propensity to theorize which these facts necessarily incite, we are led by them to the conclusion formed by their acute discoverer, that the nature of these deposites argues there having been, at some remote period, lakes of fresh water where these strata now lie, with which have

This stratum every where contains fresh water shells in abundance, without any admixture whatever of marine exuviæ. They consist, like those of the lower freshwater beds, of several kinds of lymnei, helices and planorbes; and are extremely thin and friable.

On this lies a stratum of clay, 11 feet thick, containing an unknown bivalve shell; above which is another bed of yellow clay without shells, and upon it a stratum of friable calcareous sandstone, also without shells. Above the latter lies another calcareous stratum enclosing a few freshwater shells. These beds are occasionally very compact and of a porcellanous character.

This stratum may be seen in many parts of the Isle of Wight, north of the middle range of chalk hills. On the western coast it does not extend further than Totland bay, but occurs again at Warden point, forming the summit of the cliff. Numerous blocks of it lie loose in the soil in many parts about Cowes, Bembridge and Binstead: but in the neighbourhood of Calbourne, and between that place and Thorley, several quarries are opened in it, and afford excellent stone. The rocks at Bembridge ledge and Whitecliff bay on the east side of the island are referred to this formation. (G. T. vol. ii. p. 226.) On this lies the mass of alluvium forming the summit of Headen hill.

alternated irruptions of the sea. The horizontal position of these beds denotes their being in their natural state, as well as the many shells which are found in them in perfect preservation.

LONDON CLAY.

§ 22. This stratum consists of bluish or blackish clay, which is mostly very tough, and which contains occasional beds of sand; or is mixed with greenish sand, or calcareous matter. It obtained the name of London Clay from its lying immediately beneath the gravelly soil on which London is built. It is sometimes termed Blue Clay. This clay rises to a considerable elevation in some places, as in Shooter's hill, Highgate hill, and Langdon hill a little south of Billericay in Essex, which entirely consist of it, the first rising to the height of 446 feet, and the last to that of 620 feet above the level of the sea; and the hills which rise a little south of Waltham Abbey in Essex, and immediately contiguous to the London clay, if not chiefly consisting of it, attain the elevation of 750 feet. Boughton hill in Kent also consists of this clay. It forms steep cliffs in the Isle of Sheppey, and adding the height of these to the depth of the wells sunk in the neighbourhood, it is calculated that the blue clay is in that place 550 feet thick. This clay lies beneath, and surrounds London for a considerable distance on the north, and still further on the east; extending beyond Billericay in Essex: small patches of it occur on the east of Norwich. In many places it rises nearly to the surface, being but slightly covered by vegetable mould; in others, considerable depositions of loam or brick earth, and gravel, occur upon it, and sometimes sand.

§ 23. This deposite is by some geologists considered to be *alluvial*; in other words it is by some supposed to have resulted from the ruin of older rocks. If that were the case, we should in all probability discover some traces of such ruin in it, by the sinking of wells and other occasional openings. But as it does not enclose fragments of older rocks, nor fossils belonging exclusively to them, there is no such reason for concluding it to have resulted from ruin.

§ 24. It may be said that this clay is characterized by numerous flat spheroidal nodules of argillaceous limestone, which lie in it in regular horizontal layers at unequal distances, and generally from four to ten feet apart. These nodules are known by the name of Ludus Helmontii or Septaria, from their being divided across by partitions, or veins of calcareous spar. They furnish the material of which Parker's cement is made. In their cavities, are found crystals of calcareous spar and sulphate of barytes. The London clay contains interspersed through it, sulphuret of iron, selenite, and occasionally phosphate of iron; hence, on account of its containing these salts, the water issuing from this stratum is unfit for domestic purposes (G. T. vol. ii. p. 188.) The wells of London, and on the north of it, pass through the clay from 100 to 300 feet; and when at length the water is arrived at, it rises so rapidly as scarcely to allow time for the escape of the well-digger. At Lord Spencer's at Wimbledon, the well passing through this clay is 530 feet deep. The water which is perfectly limped and almost absolutely free from salts, is therefore what is termed *soft*, and is adapted to every domestic purpose, and never fails. It rises from a stratum of sand, which, as it is known to be interposed in some places between the chalk and the London clay, is believed to belong to the plastic clay formation.

§ 25. The organic remains enclosed in the London clay are very numerous. In the cliffs of Sheppey have been found the remains of crabs, lobsters, tortoises, nautili, and the heads and bodies of fishes; most of which are mineralized by iron pyrites: 700 different fruits, or ligneous seed vessels have also been found in this stratum, very few of which agree with any known genera or species (G. T. vol. i. p. 338); and in the blue clay of Highgate hill, among other remains, was found in a petrified state, the *teredo navalis*, or *borer*, enclosed in the wood which it formerly had pierced.

This clay also contains volutæ, rostellariæ, fusus, cerithia, and crabs teeth and bones. (Smith).

The numerous vestiges of vegetables, as well as of animals, found in this stratum, whose recent analogues are now seen only in tropical climates, involuntarily leads the mind to contemplate with wonder the altered condition of this portion of the globe. Have the laws which regulate the place and motions of this earth in the system of the universe, been subjected to change? Are there in these any sources of irregularity or gradual alteration, the proofs of which can be detected? these are questions for astronomers. (G. T. vol. ii. p. 246.)

§ 26. It is conjectured that the surface of the London clay was the residence of land animals, because their bones have been found resting upon it; *not a vestige of the same remains have been found imbedded either in the clay, or in any of our strata lying beneath* it. The remains of an elephant was found at Sheppey; of the elephant, stag, and hippopotamus at Walton in Essex, as well as of the rhinoceros, and of the Irish fossil elk.

Between a stratum of sandy gravel and the blue clay, a calcareous bed was found near Kew, in which were discovered the bones of the hippopotamus, of deer and of the elephant, together with a number of small fresh-water shells, and even snail-shells. (G. T. vol. i. p. 340.)

§ 27. The tracts of London clay found in several places in Kent, Essex, and Norfolk, not being connected with the stratum lying beneath and around London, are sometimes termed *outlying masses*. The whole, however, is to be considered as one of the strata overlying the chalk, and deposited in a vast hollow, which has been termed the *Chalk basin of London*, (§ 43). The clay does not rest immediately on the chalk; for the water supplying the wells in and near London, rises from a sand which is considered to be a member of the plastic clay formation. We may therefore assume that the water of these wells percolates the sand of that formation, overlying the chalk on the west of London, and passing beneath the blue clay, forms one immense reservoir from which the wells are supplied.

§ 28. A deposite in all respects similar to the London clay, is also found in the same situation in the *Chalk basin of the Isle of Wight* (§ 43). Portsmouth is built upon it. In the dock yard, a well was sunk through this clay to the depth of 202 feet; and another, about a quarter of a mile north of Portsmouth, 126 feet: but in the town, this stratum was perforated to the depth of 266 feet without passing through it, or finding water. On the west of Portsmouth, it forms the cliffs between Lymington and Poole, and at Stubbington: and somewhat on the east of Portsmouth it has been traced by Emsworth and Chichester harbours, to Brackelsham, and thence round Selsey Bill to Pagham harbour. Bognor rocks are considered as belonging to it, since they enclose many fossils belonging to the blue clay, and although they appear to consist of a sandstone containing much calcareous matter. From Bognor to Brighton the shore in nearly flat, and the chalk lies at no great depth beneath the surface. In the Isle of Wight, the London or blue clay is seen forming the northernmost of the vertical strata in Alum Bay, (see Plate 2, fig. 1), though in a different position; and the same clay also forms the bottom of the channel termed the Solent, which is between that island and the coast of Hampshire. In all its characters and fossils, this clay is found to agree with the blue clay which lies over the chalk in the counties of Kent, Surrey, Middlesex, and Essex. (G. T. vol. ii. p. 168, 188.)

§ 29. In the counties of Norfolk and Suffolk, there are very extensive beds of marine shells, imbedded chiefly in a ferruginous sand, and *lying above* the London clay, which have been described under the name of Crag pits. Among the fossils which have been enumerated as belonging to these beds, many agree with those in the upper marine formation in the Paris basin, and others do not appear to differ from the recent shells of the neighbouring seas. (G. T. vol. ii. p. 218.)

§ 30. The London clay is, in many places, covered by an extensive bed of sand, usually called the *Bagshot sand.* It extends over Bagshot, Frimby, and Purbright heaths, in the county of Surrey, and that of Hampstead heath belongs to it. At Purbright, and many parts of the surrounding country, loose blocks of a stone are found, resembling those termed the *Grey Weathers.* This stone, composed of siliceous particles, cemented together without any intervening substance, may be considered as a granular quartz. It has more the appearance of an original formation, or peculiar crystallization of siliceous matter analagous to that of sugar, than to a substance composed of the detritus of other rocks. Numerous large and loose masses of this rock lie scattered over the surface of the chalk country, particularly in Berkshire and Wiltshire, but a bed or continuous stratum of it has not been observed. The huge erections of Stonehenge are chiefly composed of it. *Chalk flints* are sometimes imbedded in the grey weathers. (G. T. vol. ii. p. 224.)

PLASTIC CLAY.

§ 31. The existence of this formation above the chalk in England was first discovered by T. Webster; and an account of it forms a part of his luminous communication on the subject of the strata lying over the chalk, to the Geological Society, and published in the 2nd volume of its Transactions. This formation was so named in conformity with the term by which an analogous deposite has been designated by M. M. Cuvier and Brongniart, who discovered it overlying the chalk in the basin of Paris. By the term Plastic clay, we might be, at first sight, induced to suppose it to consist only or chiefly of clay, which does not appear to be the fact.

§ 32. Viewing it on the great scale, we may consider this formation as composed of an *indefinite number of sand, clay, and pebble beds, irregularly alternating.* Of these, the sand forms in England the most extensive deposition; *in which* the clay and pebbles are interposed subordinately, and at irregular intervals. The occurrence of organic remains in the different beds of this formation, is, like the alternation of the strata composing it, exceedingly irregular; sometimes they occupy the clay, at other times the sand or pebbles, and very frequently are wanting in them all. (G. T. vol. iv. p. 299.)

§ 33. The immense number of *vertical* strata of sands, marles, and clays,* about 1100 feet wide, and visible on the coast of Alum bay in the Isle of Wight, belong to this formation. (Pl. 2. fig. 1.) These strata extend quite across the isle in a vertical position, keeping parallel to the chalk, and appearing again at White Cliff bay on the east end; where, however, they are much concealed by grassy slopes. The sands, marles, and clays are of every possible variety and shade of colour, giving to the cliff in Alum bay, which is about 200 feet high, when viewed at a little distance, a very beautiful appearance. The number and variety of these vertical layers is endless: they may be compared to the stripes on the leaves of a tulip, and are almost equally bright. On cutting down pieces of the cliff, it is astonishing to see the brightness of the colours, and the delicacy and thinness of the several layers of white and red sand (some of which do not exceed the eighth of an inch), shale and white sand, yellow clay and white or red sand, and indeed almost every imaginable combination of these materials. The forms of particular parts of this cliff, when viewed near, and from the beach, are often of the most picturesque and even sublime kind, resembling the weather-worn peaks of Alpine heights. The fact is, that the rain and weather has washed and worn away the softer parts, leaving the more solid, sharp and pointed. (W. p. 160.) Among these strata are included beds of a sort of wood-coal; in some of which the remains of fruits and branches are still observable. It burns with difficulty and with very little flame, giving out a sulphureous smell. A stratum of sand, containing green particles, frequently occurs near the chalk. Some of the strata most distant from the chalk, contain several layers of large water-worn black flint pebbles, imbedded in deep yellow sand.* These strata are bounded on the south by the chalk-marle and chalk; and on the north by a stratum of blackish clay, analagous to the London clay (§ 28), and on the north of this is Headen hill, which chiefly consists of alternating deposites by salt and fresh water (§ 18), in a nearly horizontal position. (G. T. vol. ii. p. 182 & seq.)

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* Patches of *Plastic clay* are frequently found over the chalk in different places in the south of England; some of these are yellow, and are employed for the common sorts of pottery; but others are white, or greyish white, and are used for finer purposes. The coarser clay is verv frequently met with, nor are the finer kinds of very rare occurrence. In the Isle of Wight two species of plastic white clay are worked for the purpose of making tobacco pipes. A similar clay, which is used for making gallipots, is dug from the banks of the Medway. A fine light ash-coloured, nearly white clay, which is employed in the pottery works, is also dug at Cheam, near Epsom in Surrey. (G. T. vol. i. p. 344.)

Newport in the Isle of Wight is on horizontal strata. The organic remains which have been found in perforating these strata to the depth of 200 feet, are the same as those found in the vertical marles and clays of Alum bay. (W. p. 178.)

§ 34. This formation appears also to overlie the chalk in Dorsetshire. All along the north side of the range of chalk hills which extend from Handfast point to beyond Corfe castle, there is an extensive stratum of pipe clay in a horizontal position. It contains a bed of coal so exactly resembling that of Alum bay, that this circumstance, added to the quality of the clay, and its position above the chalk, is sufficient to identify it. The same stratum of clay, though not of equal quality, may be traced in the hills near Poole, and is found in many parts of that extensive tract called the trough of Poole. (W.)

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* See remarks on the vertical position of these and the chalk strata in § 18.

§ 35. It is observed by T. Webster that this formation appears at Reading (G. T. vol. ii. p. 186.) and is seen at the bottom of the blue clay in many parts of the London basin. (W. p. 26.)

A very interesting communication on this subject has since been made by the Rev. W. Buckland, to the Geological Society, and is published in the 4th volume of its Transactions: the following particulars are chiefly extracted from it.

§ 36. An attentive examination of the general points of resemblance in the substance of the clays, sands, and pebbles, forming these irregular alternations above the chalk, leaves no doubt as to their being members of *one great series of nearly contemporaneous depositions*, intermediate between the chalk and the London clay.

The organic remains enclosed in these beds, consist of oyster shells, the teeth of fish, cerithia, cythereæ, and cyclades, together with chalk flints, coaly matter, selenites and fibrous gypsum, and leaves of plants.

§ 37. But in order to present a distinct idea of the nature of the beds constituting this formation, it will be advantageous to quote one example of the numerous sections given in the Rev. W. Buckland's communication. I select therefore that with which the author begins, namely, that of the Catsgrove brick-kilns, distant about half a mile from the town of Reading, on the south-west, where the works have been carried on for more than a century, and at this time present the following section, beginning from the chalk on which these beds constituting the plastic clay formation rest.

Section of Catsgrove Hill.

No.		*thickness in feet.*
1.	Chalk containing the usual extraneous fossils and black flints	unknown
2.	Siliceous sand mixed with granular particles of green earth, and containing both rolled and angular chalk-flints, oysters, and many small and nearly cylindrical teeth of fish from a line to an inch in length*	3
3.	Quartzose sand of a yellowish colour with a few small green particles, and containing no pebbles or organic remains	5
4.	Fullers' earth	3
5.	White sand used for bricks	4
6.	Lowest brick clay of a light grey colour mixed with fine sand, and a little iron-shot	8
7.	Dark red clay, mottled with blue and occasionally a little iron-shot. It is used for tiles	6
8.	Bed called the White vein. A fine ash colored sand mixed with a small portion of clay and in some parts passing into loose white sand. It is used for bricks	5
9.	Fine micaceous sand laminated and partially mixed with clay, and occasionally iron-shot. It is used to make tiles	4
10.	Light ash coloured clay, mixed with very fine sand of the same colour. It is used for bricks	7

* There is not the smallest trace of animal or vegetable remains in any of these strata above the chalk, excepting in the green sand. The same barrenness of organic remains is noticed in the purest beds of the French plastic clay, and by Mr. Webster (G. T. vol. ii. p. 200) in the plastic clay of the Isle of Wight and Corfe Castle.

	thickness in feet.
Dark red clay partially mottled and mixed with grey clay - - - - - - - - -	4
Soft loam, composed in its upper region of fine yellow micaceous sand, mixed with flakes of a delicate ash coloured clay, which become more abundant in the deeper portions of the stratum, and having its lower regions much iron-shot, and occasionally charged with ochreous concretions, and decomposing nodules of iron pyrites It is used to make soft bricks for arches - - - - - - -	11
Total	57
Alluvium composed of clay, sand and gravel, the gravel chiefly consisting of chalk flints, both rolled and angular, with a few pebbles of quartz, and of brown compact sandstone. This alluvium is covered with vegetable mould - - - -	—

The oysters of No. 2 are remarkably perfect when first laid
n, and seem to have undergone no process of mineralization;
y soon fall to pieces by exposure to air and moisture. The chalk
ts contained in it are many of them in the state of small rounded
bles; in others the angles are unbroken. Both varieties are
ered with a crust of greenish earth of the same nature with the
en particles in the sand. The angular flints appear to have
n derived from the partial destruction of the bed of chalk im-
liately subjacent, of which the upper surface in contact with
sand is considerably decomposed to the depth of about a foot,
its fissures and numerous small tubular cavities (the latter de-
d apparently from the decay of organic substances) are filled
h granular particles of the green earth and siliceous sand, the
umbent stratum.

In other large quarries of brick earth on St. David's
l, west of Reading, and only a quarter of a mile dis-
t from the Catsgrove, many of the subdivisions noted
the latter do not occur.

§ 38. This formation occupies much of the ground between Reading and Newbury, and is seen at Hermitage on the north-east of Newbury towards Hampsted Norris: whence a range of low hills composed of them stretches eastward towards Reading, and westward to Boxford, Wickham, and the neighbourhood of Hungerford, interrupted by vallies which are often cut down into the subjacent chalk.

The breadth of this deposition on the north and south of Newbury, is, from Beedon hill, six miles north on the road to Market Ilsley; to Whitway near Highclere, four miles south of Newbury on the road to Whitchurch. On the west of this line, drawn through Newbury north and south, the breadth *of the beds on the chalk* is gradually contracted till they entirely cease near Hungerford. (See Mr. Webster's Map, G. T. vol. ii. plate 10.) On the east side of the said line, they occupy the vale of the Kennet till it falls into that of the Thames, near Reading; whence they extend eastward, widening as they advance through Surrey and Middlesex, into Kent, Essex, Suffolk, and Norfolk.

§ 39. In many parts of this great valley of chalk, which has been termed the chalk basin of London, the Reading beds are recognized in their proper place, as the inferior strata of the plastic clay formation; though, with the exception of the lowest bed, they do not agree in minute detail with those of the Reading section.

Near London, these beds occur with well defined characters, at Blackheath, Lewisham, Charlton, Woolwich, and on the east of Plumstead. In all these places, *the thin bed next above the chalk*, which at Reading contains fishes teeth and oysters, is composed of a similar substance of loose sand mixed with chalk flints, both rolled and angular, and generally coated with a dark green crust; but *here they contain no organic remains*, and seldom exceed two feet in thickness. Above this thin bed, is a stratum of fine grained ash-coloured sand, destitute of shells or pebbles, and varying in thickness generally from thirty to forty feet. This stratum is seen to the grearest advantage in the Woolwich sand-pits, which present an enormous artificial section. In this is a bed of blue and brown clay (next but two beneath the alluvium), which is striped and full of shells, chiefly cerithia and cythereæ. The next bed of clay above it, contains a few shells of the same species; and the next, which is immediately below the alluvium, consists of rolled flints with a little sand, occasionally containing shells of the same species, and oysters, disseminated in irregular patches. In the middle one of three pits on Loam Pit hill, near Lewisham, are three thin beds of clay, of which the upper and lower contain cythereæ, and the middle one, oysters. In the upper pit, the lowest stratum, a brownish clay, contains cythereæ; a lead-coloured clay above it contains impressions of leaves; then yellow sand; above which is a striped loam and plastic clay, containing a few pyritical casts of shells, and some thin seams of coaly matter. Then succeeds a bed of sand, on which lies an alluvium, in which have been found the tusks of elephants. (§ 5.)

Similar beds may be traced round the sloping terrace that bounds the north-west and south sides of the plain of Blackheath, the surface of which consists of a bed of rounded pebbles, resting on another of plastic clay, which supports the water of all the wells on Blackheath, and possesses the same peculiar dark red colour with the plastic clay of Reading, Corfe Castle and Paris, and has been used for pottery.* Shooter's hill consists of the London clay.

§ 40. From the foregoing, and other circumstances detailed in the communication from which they are extracted, it is concluded that the formation of the plastic clay extends over a large space in the south portion of the valley of the Thames from Reading to Gravesend. There are some appearances of it still further on the borders of that river, and even close to Margate.†

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* It is probable that the plastic clay contains at Blackheath, as at Corfe Castle, Alum Bay, and Loam Pit Hill, the remains of vegetable matter in a state approaching to coal; and that this circumstance has given origin to the erroneous opinion so prevalent, that there is good coal at Blackheath, if government would allow it to be worked.

The very high improbability of finding good coal above the chalk, is acknowledged by all who have even the smallest acquaintance with the geological relations of the English coal mines. The presence of black vegetable matter in a state approaching charcoal in almost all our secondary argillaceous strata, has caused endless vain attempts to search for useful coal, in formations where the discovery of that substance would be contrary to all experience in this country. No good coal has I believe been yet found in England in any stratum more recent than the new red sandstone, or red rock marle. That of the Cleveland moors in Yorkshire being above lias and in the oolite formation, is of so bad a quality as scarcely to form an exception to this position. (G. T. vol. iv. p. 289.)

† On the authority of Wilson Lowry, Esq. I am enabled to state, that in some beds belonging to the plastic clay formation in the immediate vicinity of Margate, fossil bones have lately been discovered.

§ 41. On the coast of Sussex, this formation is visible between Newhaven and Beachy Head, in the cliff at Chimting Castle, half a mile on the east of Seaford; and also on the Castle hill at Newhaven. These portions of this formation, as well as others at the south base of the chalk hills of the south-downs of Sussex, appear to be fragments at the eastern extremity of *the great series of depositions above the chalk* in the south of England, which are described as extending from near Dorchester by the Trough of Poole and the New Forest to Portsmouth, Chichester, and the flat coast on the south-east of Arundel. (G. T. vol. ii. and Map pl. 10*.) Here they enter the English Channel, and just touching the coast with their outlying fragments at Newhaven and Chimting Castle, appear again on the opposite shores of France in the same relative position.

CHALK.

§ 42. The chalk formation of England is very extensive. The extreme points at which it appears on the west, are near Sidmouth and Honiton in Devonshire. About twenty-five miles east of the latter place, an extensive range of chalk hills begins, extending in a north-easterly direction to the northern coast of Norfolk; and through Lincolnshire to Flamborough head in Yorkshire, interrupted only by the course of the Humber through it.

From near Honiton also the chalk branches off towards the south-east to the Isle of Purbeck, and appears again ranging through the center of the Isle of Wight. Near Hungerford in Berkshire, another range of hills commences, extending by Alton and Rochester to the coast of Kent, where its natural section forms the cliffs between Folkstone and Deal. From near Alton still another range proceeds circuitously to Beachy head.

Wherever chalk appears, the hills consisting of it are remarkable for their smooth rounded outline, and for the deep hollows or indentations on their sides.

Near Royston it attains an elevation above the sea of 481 feet; south of Dunstable of 994 feet; south of Shaftesbury of 941 feet; between Lewes in Sussex and Alton in Hampshire, various parts of the range rise to the height of between 800 and 900 feet, and the range between Alton and Dover, between 700 and 800 feet.

The hill on which Dover Castle stands is 469 feet above the sea; the cliffs near Folkstone are 550 feet high, and those near Lyme in Dorsetshire are 580 feet.

The organic remains found in the chalk deposite are numerous. The forms of sponges are visible both in the chalk, and in the flints which it encloses. Appearances of alcyonia are also visible. Echinites are plentiful both in the chalk and flint; the shell is commonly replaced by carbonate of lime. The teeth and palates of fishes are not rare. Fragments of a large striated shell termed the inoceramus are very plentiful, and among other shells occur ostreæ, plagiostoma, pectines, terebratulæ, and casts of large ammonites; in the grey chalk, the casts of nautili; and I have lately found near Dover, the cast of a shell in flint, which is considered to be the teredo navalis; belemnites in some places are not uncommon.

§ 43. It has been ascertained, in many places, that the chalk of the long range of hills extending from Hungerford in a north-easterly direction to the coast of Norfolk, dip towards the south-east, passing beneath the sands and clays of Berkshire, Middlesex, Essex, Suffolk, and Norfolk. It is also known that the range from Hungerford to Margate in Kent, dip under the same sands and clays in a northerly direction. Hence it is concluded that all the sands and clays lying within the triangle of which Cromer, Hungerford, and Margate may be said to form the points, lie in an immense hollow in the chalk, which is supposed to pass beneath the sea between Margate and Cromer. This hollow or depression in the chalk has been termed the *Chalk basin of London*.

Another depression of the chalk occurs on the Southern Coast, which also may be said to be comprehended in a triangle, of which the northern point is a few miles on the east of Salisbury. From that place, one side extends south-west to near Blandford in Dorsetshire, another south-east to near Brighton in Sussex, and the third extends from Brighton to Blandford, ranging through the centre of the Isle of Wight. This depression is termed the *Chalk basin of the Isle of Wight.* All the beds within that basin, are above the chalk.

An inspection of the Map might induce the supposition that there exists still a third basin, comprehended within a triangle, of which the points are Dover, Alton, and Beachy head. Within this space however, the strata are not above, but *below* the chalk, being the same with those on the west of the chalk range between Hungerford and Salisbury, namely, the iron sand, blue marle and green sand; which therefore, it is concluded, pass beneath the chalk. So that, a depression in these strata contains the chalk between Alton and those places. (See pl. 2, fig. 3.)

§ 44. The chalk formation consists of several strata, or beds, of somewhat different characters. These have been variously designated. By some, three varieties only have been distinguished; namely, the Upper or Flinty chalk; the Chalk without flints; and the lowermost stratum, which, being of a greyish colour, is termed Grey chalk: others separate the flinty chalk into two beds; the uppermost containing numerous flints, lying upon the other, which contains but few: in some places this distinction is well characterized. That all the beds are of one formation has been ascertained by their containing nearly, if not quite, the same organic remains. In some places there lies upon the chalk, as well as beneath it, a stratum which, as it consists of chalk intermingled with some argillaceous matter, is termed *Chalk-marle.*

Of the many formations which consist of numerous beds, there are few, if any, that, throughout their extent, exhibit all the beds which properly belong to them. This is remarkable in the chalk formation. In most places, the chalk-marle is wanting; in many, the grey chalk; in some, the upper chalk. In no one place, that I am aware of, has the whole series been seen. But as yet we have by no means a sufficient account of this extensive deposite. In some places it has been pretty accurately examined. I shall begin with an account of the marle.

§ 45. *Chalk-marle* lies *above the chalk* in the Isle of Wight; or rather, it is interposed between the nearly vertical chalk of Alum bay, and the vertical and many coloured beds of clay, sand, &c. constituting the formation termed the *Plastic clay* (Plate 2, fig. 1.) But I am not aware of its having been seen above the chalk in any other part of England.

Below the chalk, the chalk-marle is of pretty extensive occurrence. It underlies and crops out on the south of the central chalk range of the Isle of Wight: it also underlies the chalk range of Dorsetshire from Handfast point to Lulworth.* It consists of chalk and an intimate mixture of clay, and may readily be distinguished from the chalk, by its falling to pieces on being wetted and dried again (W. p. 236.) It is never quite so white as chalk, having generally a tinge of yellow, and sometimes of grey or brown. It also contains nodules or beds of a more indurated marle, which is usually called *grey chalk* from its dark colour. Like all argillaceous limestones, it possesses in a considerable degree the property of setting under water, when calcined and made into mortar, and was used in the building of the London Docks. It is also used as a manure. (G. T. vol. ii. p. 174.) Chalk-marle of a white colour, forms the superior stratum of St. Catherine's Down in the Isle of Wight, lying in a horizontal position. It also lies on the top of the undercliff of that isle, the whole of the way, but is of variable thickness: opposite to Old Park it is highest, and it may there be distinctly seen that it is stratified, the strata being horizontal (W. p. 143.)

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* The green sand, blue marle, and ferruginous sand underlie the chalk marle, in the order in which they are mentioned, along the whole course of both these ranges; the latter forming the plains on their south. (W.)

§ 46. The *Upper* or *Flinty chalk* appears through a considerable part of the large tract of England occupied by the chalk formation, though its limits are by no means ascertained. It is however so nearly universal, that where it is wanting, it is commonly considered to have been destroyed, or carried away by some of the numerous convulsions to which there exist so many proofs that the earth has been subjected. Almost every where in the neighbourhood of chalk hills, the alluvium consists in part of flints more or less rounded by attrition, some of which still retain the white coating common to chalk flints. In the interior of England, occasional openings discover the prevalence of the flinty chalk, but it is on the coasts that we must look for the more decided characteristics of this extensive formation. We have no description of the chalk cliffs of the north of England, but those of Dorsetshire and the Isle of Wight especially} have been described. The cliffs of the neighbourhood of Dover are scarcely inferior in interest.

§ 47. The common position of the numerous beds of flints in the upper chalk is so nearly horizontal, that we may conclude the natural position of the chalk strata to be *nearly flat.* A remarkable deviation from this general rule is however observable in the Isle of Wight, and on the coast of Dorsetshire; for on their coasts the beds of flint are *nearly vertical.*

§ 48. In the admirable letters to Sir H. Englefield by T. Webster, we have an excellent account of the chalk of those places. The central range of hills of the Isle of Wight, from White Cliff bay on the east, to Alum bay on the west, consists of nearly *vertical* strata of chalk (see Plate 2. fig. 1.) In both those bays, the beds of flint are nearly in that position; which, many circumstances contribute to prove, is not the natural position of that range. The flints are not whole; but even while lying in the chalk, are cracked into numerous pieces, which has never been observed when the flints are in horizontal layers; and the vast number of strata of sand and of clay, lying on the north of this range, are also in a vertical position; but these strata, which belong to the plastic clay formation (§ 33), lie in the contrary direction in other places. Hence, it is concluded that this chalk range has been thrown down, either by subsidence on the one side, or elevation on the other, together with these now vertical strata of sands and clays, from their natural position to that in which they now lie. A conclusion of the utmost probability.

§ 49. The almost vertical chalk range of the Isle of Wight, is nearly on a line with the chalk range in the same position near the coast of Dorsetshire, and extending from Handfast point to Lulworth. At Handfast point the face of the cliff presents a remarkable configuration of the chalk strata. On the north, these strata are nearly horizontal, but they rise with a regular curve forming about a quarter of a circle, lying upon chalk in nearly vertical strata. It is so impossible that description should do justice to this extraordinary fact, that I annex a sketch taken from one of the plates accompanying T. Webster's letters to Sir Henry Englefield, and published in his splendid work, the 'Description of the Isle of Wight.'*

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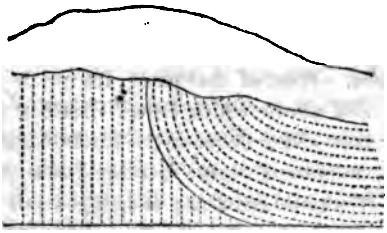
* In the chalk at Bat's Corner and White Nore, on the Coast of Dorsetshire, some miles east of Weymouth, some extraordinary contortions of the strata are visible. Views of this part of the Coast are given in the work above quoted.

The hardness and specific gravity of the vertical chalk at Handfast Point, are so considerably superior to the chalk of other places, that it has been sometimes called white limestone, and considered to belong to a different formation, but its organic remains, and its connection with the green sand and other strata, almost every where underlying chalk, shew their identity.

If we still extend our consideration to the middle chalk range, of the Isle of Wight, and compare its direction with that on the Coast of Dorsetshire, and if moreover we consider, that the strata of both are vertical or nearly so, we shall coincide in opinion with Si H. Englefield, that these two ranges were once in connexion; and that they have been separated by the sea at some remote period.



In the vertical strata, the flints, instead of being nodular, consist of sharp fragments lying in detached masses or groups: while those in the nearly horizontal strata, are, as is usual in the chalk of many parts of England, in nodules. It may be argued from these facts, that, from some cause with which we are unacquainted, the vertical part of the cliff had fallen from its natural position, previously to the deposition of the curved strata. The nearly vertical strata have been traced almost the whole of the way from Handfast point to Lulworth.

Next to the vertical strata of the Isle of Wight, on the north, and between the chalk and vertical sand, &c. is a stratum of chalk-marle (Pl. 2, fig. 1.) On the south, are nearly vertical beds of chalk without flints (not visible in that figure); then succeeds chalk-marle; then the green sand, and the blue marle. These are visible on the southern coast: and each stratum declines more than the preceding from the perpendicular, until the latter reposes on nearly horizontal strata of the iron sand. (See G. T. vol. ii. pl. 11.)

§ 50. The chalk cliffs between Deal and Folkstone are extremely interesting. A short distance on the west of Deal, the chalk with numerous flints rises from beneath alluvial sand, and continues to rise, constituting the whole cliff for about five miles; namely as far as St. Margaret's Bay, where the summit is about 150 feet above the sea. West of that place, its rise is gradual as far as the cliff above which Dover Castle stands; and the greater part of it, beneath the castle, consists of the chalk with numerous flints; but the lower part of the bed is full of organic remains; of sponges and echinites, &c. of which the traces are visible on the surface of the cliff, projecting from it in the form of knots of a colour somewhat darker than the chalk itself. The beds of flint between Deal and St. Margaret's Bay, are numerous and thin; but between the latter place and Dover they increase in thickness; and the flints are not nodular, but form beds of irregular thickness, with occasional cavities. The lower part of the cliff, beneath the castle, consists of *chalk with few flints*, in which lie some beds of soft chalk-marle; which, as it falls away by exposure, leaves crevices by which the stratification is easily traced. These crevices rise from the beach midway between St. Margaret's and Dover; are visible beneath the castle about one-third of the way up the cliff; are again seen in the cliff at the back of the town at a higher elevation, and again near the summit of Shakespeare's cliff on the west of Dover; proving the regular stratification of the chalk and its gentle dip. The low cliff commencing on the west of Dover, consists of a stratum of chalk containing numerous beds of sponges, and other organic remains, *but no flints*: this bed forms the great body of Shakespeare's cliff, from the base, to where it underlies the chalk with few flints near the summit, and continues to rise for five miles westward; until, near Folkstone, where the cliff is 550 feet high, it forms the greater part of the upper half. Immediately at the foot of Shakespeare's cliff, a new stratum rises from the beach, consisting of chalk, *also without flints*, containing few organic remains, and about 50 feet thick; it is separated from the superincumbent bed, by a bed of marle, which may be seen with little interruption for five miles. A little on the west of Shakespeare's cliff, the *grey chalk* rises, and may be traced to where the high cliff terminates above Folkstone. This chalk is of a grey colour, is softer than common chalk, contains some alumine, and the same kind of organic remains as are commonly found in chalk, and some thin beds of sandstone, but no flints. But it is impossible to discover the thickness of this bed, for though the cliff near Folkstone is 550 feet high, a most enormous and picturesque ruin covers its base. It is however probable that the chalk there rests upon a bed of blue marle (§ 59, note), and that the giving way of this stratum has been the cause of the ruin. The marle is seen lying on the green sand at Copt Point near Folkstone, and at places between that point and the chalk hills. In the cliffs east and west of Dover therefore, we have all the members of the chalk formation, except the marles; which, in the Isle of Wight, lie above and below the chalk properly so called.

§ 51. The chalk of Cambridgeshire is described as consisting of two varieties; the *upper* containing the common black flint in abundance, and the lower or *grey chalk*,* which contains little or none. If a line be drawn from Royston by Balsham to Newmarket, it will pretty exactly define the limits of both varieties; the hills to the eastward of it being composed of the upper beds, while those to the west, consist of the lower or grey chalk, which composes by far the greatest part of the hills of Cambridgeshire. It is considerably harder than common chalk, and its colour is usually some shade of grey. Its provincial name is *clunch*, and it yields the best lime. Some of the beds are hard enough to serve the purpose of building stone. It also endures the fire well; and is used, like that of Riegate and Measham in Surrey, for the backs of grates. In the northern extremity of the Cambridgeshire hills, the chalk appears to rest upon an extensive bed of blue clay, termed *gault*, but there is no decisive line of separation between them (§ 60): they are considered to pass into each other by degrees, the lower beds of the grey chalk becoming more sandy, and assuming gradually the nature of an argillaceous loam. (G. T. vol. iii. p. 243, & seq.)

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* Grey chalk is found below the chalk without flints near Arreton Church, not far from Ryde in the Isle of Wight, and also at Guildford and Dorking in Surrey. It is, in fact, in these places, an indurated chalk-marle or argillaceous limestone (W. p. 177) but differs from the grey chalk of Dover.

§ 52. In the Wolds of Lincolnshire, the chalk consists of two colours, red and white, each lying in regular strata, the red being generally undermost; in the white, seams of flint are frequently met with from two to six inches thick. The chalk rests upon a coarse brown pebbly sand without organic remains, consisting of quartz and oxide of iron. (G. T. vol. iii. p. 394.)

§ 53. The beds of flint occurring in chalk do not always consist of separate nodules, but have been observed in many places forming continuous and nearly flat tabular masses or layers. Between Deal and St. Margaret's Bay, I have traced one layer for about two miles along the cliff; it no where exceeds an inch and a half in thickness; and another layer about half an inch thick for about a mile. Sometimes however the flint is seen in veins nearly vertical, or not greatly differing from that position.

In the chalk pit on Arreton down, near Ryde in the Isle of Wight, flint occurs in laminæ which chiefly occupy the diagonal fissures that cross, at various angles, the general direction of the strata, dividing the whole into rhomboidal forms. (W. p 176.)

§ 54. That the chalk strata of England have suffered much injury and ruin, is evident not only from the immense quantity of flint lying in the alluvial matter in their neighbourhood, but also from the great deposites of rounded chalk, or *chalk rubble*, seen in many places, filling up hollows or intermixed with other alluvium.

The mass of chalk rubble forming the cliffs at Brighton, and on which there is reason to suppose that the town is built, rests, on the east of the town, on a bed of shingles or rounded stones of considerable size, varying from eight to ten feet in thickness. This bed consists chiefly of flint, but contains rounded masses of *granite, slate, and porphyry*, strongly cemented together by stalactitical matter, being carbonate of lime well crystallized, and formed probably by the infiltration of water from the overlying bed of chalk rubble. It thus constitutes a hard breccia, which, in the large masses lying upon the beach, resists all the force of the waves. It contains within it small beds of fine white loose sand. The bed of shingles, about a mile east of Brighton, is seen resting upon chalk, containing nodules and continuous veins of flint; the latter intersecting it in all directions, from the horizontal to the perpendicular. The chalk rubble is described as assuming *by degrees* a more regular aspect, and as having the appearance of chalk about half way between Brighton and Rottingdean: so that the upper part is said there to contain two layers of flint, lying in their natural bed of chalk. Still the bed of shingles may be observed, but is much thinner than on the west, being only a few inches thick; but one circumstance described as happening at this place is very remarkable—namely—that some *oblique veins of flint traversing the chalk from the base of the cliff to the two horizontal veins near the summit, pass through the bed of shingles.* The chalk above the shingles, again assumes the appearance of chalk rubble in approaching Rottingdean, and some remarkable contortions of what are said to be strata of flint, appear in its neighbourhood, especially on the east of it. (R. I. J. No. viii. p. 227.)

GREEN SAND.

§ 55. This stratum has received the name of Green Sand from its containing little round masses of a green substance, having a considerable resemblance to chlorite, which sometimes are so numerous as to give a green tinge to the aggregate of which they form a part. It is sometimes considerably compact and hard, bearing the characters of a sandstone rather than of sand.

Though the geological position of this rock is immediately beneath the chalk, it has not yet been ascertained with certainty to what extent it accompanies the immense chalk deposite of England. It has been seen in many places on the western side of the chalk range, extending from Dorsetshire into Yorkshire, but it is best observed on the coast; as of Dorsetshire and Kent, and of the Isle of Wight. It has been seen cropping out from beneath the chalk range bordering the Isle of Purbeck, and the central range of the Isle of Wight; and is also visible on the southern side of that isle. The pier of Folkstone in Kent is constructed of masses of green sandstone; which lies in regular layers in the green sand, on which Folkstone is built.

For the account of the characters of this stratum we are indebted to the very interesting letters of T. Webster to Sir Henry Englefield, as well as for almost the only information that we possess of the succeeding stratum—the blue marle. The fossils commonly found in the green sand, are, alcyonia, venus, chama, pectines, terebratulæ, echini, (Smith); large ostreæ sometimes abound in the sandstone, or in the chert it encloses.

§ 56. The green sand consists of siliceous sand sometimes united by calcareous matter, and enclosing mica and green earth. But the latter is sometimes greyish: the two colours passing imperceptibly into each other. It is found in the wealds of Kent and Sussex, at the foot of the chalk downs, and is dug at Ryegate and Me[illegible]sham for *fire-stone*. It is seen also at Folkstone, Beachy head, the Culver and Compton bay in the Isle of Wight; at Pewsey in Wiltshire, &c. Alternating with it are often beds of limestone, as at Maidstone in Kent, where they are called *Kentish Rag*, also at Undercliff in the Isle of Wight. Beds of chert occur in it; it abounds in organic remains. (W. p. 237.)

§ 57. In the Isle of Wight it consists of siliceous sand, mixed with mica, green earth, and a considerable quantity of calcareous matter. In the upper part, there are a great number of irregular layers of chert, alternating with the sandstone, with which it is sometimes mixed in a very singular manner. Between some of the layers of chert, the sand is white and perfectly loose; in other places, it is more or less cemented by calcareous matter. The sand and chert are in some places intersected by numerous veins of chalcedony. About 30 feet from the top of the cliff on the southern side of the island, there is a bed of sandstone about four feet thick, which extends all along it, overhanging the *undercliff*. It is a good building stone, is soft when first taken out of its bed, but hardens by exposure. All the ancient Gothic churches on the north side of the island, have been constructed of it. Below this bed, the sandstone is soft, and unfit for building. The remaining part of the stratum encloses beds of limestone of a bluish, and sometimes of a reddish colour, and layers of flattened nodules of the same substance. In the Isle, this limestone is called *Rag*: it is identical with the well known *Kentish Rag*. The calcareous matter which is mingled with the sand in the *freestone*, and which forms its cement, is generally white and very friable, but sometimes, as at the western lines, it is crystallized, forming with the sand a greenish grey rock. When this is the case, it is scarcely acted upon by the waves or the weather. On masses of this rock, on the shore, are the forms in relief of a fossil organic body, supposed to be a species of zoophite, or animal possessing a vegetable form, and is the same described in the second volume of the Geological Transactions under the name of alcyonium. (W. p. 146 & seq.)

The remains of the alcyonium resemble in some cases only the branches of trees, varying from half an inch to three or four inches in diameter, and consisting of sandstone of the same kind as that in which they are imbedded, but the part resembling the bark, being somewhat harder, projects above the surface; sometimes these branches are terminated by bulbous heads, and even occasionally exhibit the appearance of roots. These are numerous about Ventnor Cove, and in various parts of the undercliff. At the western lines also, varieties of the same fossil are plentifully found on the surfaces of the rocks belonging to the green sandstone formation, which slid down into the sea at the time when the great failure of the sratum took place which occasioned the undercliff. (G. T. vol. ii. p. 377 & seq.)

§ 57.* In the neighbourhood of Folkstone, the green sand encloses beds of sandstone, dipping gently, to the north-east, and in that respect agree with the stratification of the chalk of the neighbouring hills, beneath which the sand passes. It does not appear however to be immediately in contact with the chalk; for there is reason to believe that, in the vicinity of Folkstone, and there only as far as has yet been observed, a bluish marle is interposed. This marle encloses a vast number of shells, exhibiting the nacre in high perfection, and even some shells that have not been observed in any other stratum (§ 59. note). The sandstone encloses masses of chert, the stems of alcyonia, large oyster shells, and various other organic remains.

BLUE MARLE.

§ 58. This marle, as its name implies, is of a blue colour, or of a bluish black. It contains very few fossils. (W. 237) Its geological position is between the green sand and the ferruginous sand.

It lies between them from a little to the south-west of Salisbury to the north-west coast of Norfolk, though not without interruption, which principally takes place in the low swamps of the Isle of Ely. It scarcely appears in the northern parts of England. It is the blue marle of Shotover hill in Oxfordshire, in which are found the fine crystals of selenite; but in general it attains but little elevation; more often it is low, as may be observed in the vale of Aylesbury in Buckinghamshire, and in that of the White horse in Wiltshire. It forms a tenacious soil, remarkable for the growth of some of the finest oaks. (S. p. 43.) It contains belemnites and ammonites. (Smith.)

§ 59. It may be seen under * the green sand very distinctly in the Isle of Wight; as at Sandown Bay, many parts of the Undercliff, Niton, and Compton. (W. 237.)

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* A blue marle is found near *Folkstone* in Kent, which does not appear to belong to this formation; since, instead of lying *beneath*, it lies *upon* the green sand: and as this blue marle, which contains a great number of organic remains and shells, encloses some shells which have not been discovered *in any other* of the English strata, it seems reasonable to conclude that although the mass at Folkstone is comparatively very small, it ought to be considered as a separate formation. Its geological position appears to be between the grey, or lower bed of chalk, and the green sand. The

The strata forming the perpendicular rocks at the Undercliff in the Isle of Wight, consist of green sandstone and chert (the latter being a subordinate bed to the former) lying on a stratum of blue marle. Whenever the land springs act on this latter stratum, it becomes of the consistence of mud, runs out, and leaves the sandstone without support; which, being deprived of its foundation, of course tumbles down. (W. p. 134.) To this circumstance is to be attributed that immense ruin which forms the striking feature of the Isle of Wight; and which being now variegated by rocks, and woods, and cottages, and corn fields, is become the principal attraction of the visitors to the island.*

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lowest part of the bed contains abundance of pyrites in a decomposed state, selenite, and the trunks and branches of trees, in some specimens of which the woody fibre yet remains.

This circumstance seems to point out that some part of the earth at least must have been covered by vegetation previously to the deposition of this stratum, and consequently before the deposition of the chalk. We may however go further back. Calcareous beds of much earlier date also enclose the remains of trees, and even some of the sandstones which may be reckoned amongst the oldest of the flœtz rocks are similarly characterized. These facts alone afford material for reflection upon the numerous changes which the Earth must have undergone by the agency of water. It sufficiently proves of itself, the assertions of geologists that there have been many irruptions and retreats of the sea,—and that these irruptions have taken place at times so distant from each other, as to allow of the earth's being covered by vegetation between their periods.

* The cliff above this ruin having been exposed for ages to the action of the air, has suffered much, though unequally, in different parts, according to the nature of the layers. The chert, which forms the upper part, being hardest, is scarcely at all affected; the limestone suffers more, wearing into holes: while the soft sandstone moulders very much, leaving deep cavities between the beds of chert and limestone. (W. p. 143.)

In the neighbourhood of Black-gang chine this stratum is very visible. It was the cause of a great land-slip which took place in the year 1799, and of another fall 8 or 10 years ago; springs of water, to which both may be attributed, still continue to make their way through the blue marle on the east of Black-gang chine.

It underlies the green sand beneath the central chalk range of the Isle of Wight, and the chalk range from Handfast point to Lulworth in Dorsetshire.

§ 60. The northern parts of the chalk range in Cambridgeshire, rests upon an extensive bed of blue clay, provincially called *gault*, with which the lowermost stratum or grey chalk is so intermixed, as that no decided line of separation has been observed. They are considered to pass by degrees into each other. The lower beds of grey chalk, provincially termed *clunch*, become more and more sandy, and gradually assume the nature of an argillaceous loam. In the next observable stage of transition, the mass assumes a greenish grey colour, and a plentiful admixture of dark green sand is uniformly dispersed through its substance. At the same time, it contains numerous dark brown nodules of a ferruginous indurated marle. At length these foreign matters disappear; the mass becomes uniform, and ends in the bluish clay or argillaceous marle called gault. (G. T. vol. iii. p. 243 & seq.)

From this description, it seems reasonable to conclude that the lowermost bed of the chalk formation in this district is a chalk-marle, which is associated so intimately with the green sand and the blue marle, which commonly underlie the chalk formation, as to cause their being blended together. It does not however appear to have been decided that the gault is a member of the blue marle now under consideration, or of that which is briefly noticed in the note at p. 64, which could only be proved by a comparison of their organic remains.

FERRUGINOUS, OR IRON SAND.

§ 61. This also is an extensive deposite. It appears on the southern coast of the Isle of Wight, on the coast of Dorsetshire, forms a considerable range of hills in Surrey, and may be traced with remarkable regularity from within a few miles south of Shaftesbury in Dorsetshire, nearly to St. Neots, in Huntingdonshire. It appears again on the eastern coast of Norfolk, and reappears at Spilsby in Lincolnshire for a short distance; and again in Yorkshire, accompanying the clunch clay, which is there termed alum-shale, to the northern coast of that county, covering the surface of a large district in the western parts of it.

Being an older formation than the chalk, the iron sand passes beneath it, as is shewn by Plate 2, fig. 2, though it is not the stratum lying immediately beneath the chalk. This observation is made here, in order to carry the reader's attention to the section exhibited by fig. 3 of the same plate, on which it is shewn that the iron sand on which Devizes stands on the western side of the chalk, passes beneath it, forming on the east of it, a large proportion of Kent and Surrey, and indeed the principal part of the large district comprehended in a triangle, of which Dover, Beachy Head and Alton form the points; rising into a considerable range of hills, of which the summit of Leith hill is the highest point.

So that the whole of this tract, consisting chiefly of the ferruginous sand, and partly of the blue marle and green sand, is older than the chalk which surround it. It is the more needful to make this observation, since its appearance on the map might give rise to the idea, that this tract consists of strata deposited in a vast hollow in the chalk, termed a chalk basin; whereas, on the contrary, all the substances within this space, and which have just been enumerated, actually pass beneath the surrounding chalk hills.

Leith hill in Surrey, though it rises to the height of 993 feet above the sea, is not the greatest elevation attained by the iron sand; for near its termination on the coast of Yorkshire, it rises to the height of 1485 feet, at a place called Bottom head. In general however it does not attain considerable elevation. Where it rises to the surface, it affords in some places little else than heath; but in others, as surrounding Woburn in Bedfordshire, it is now covered by extensive plantations of firs.

§ 62. This formation consists of an alternating series of siliceous sandstone, clay, and limestone. The sandstone always contains oxide of iron, but in variable quantity; but sometimes it prevails so greatly, as in the wealds of Kent and Sussex, that it was formerly employed as an iron-ore. The clay tracts of the wealds of these two counties, and the sand of Hastings and Tunbridge Wells, &c. belong to this formation; as well as that of Sandown bay and Black-gang and Compton Chines in the Isle of Wight, and of Swanwich bay on the coast of Dorsetshire. Fossil shells are rarely found in it (W. p. 237); but it contains organic remains, amongst which are ammonites and the nautilus. In the vicinity of Woburn in Bedfordshire, there rest upon the ferruginous sand considerable deposites of fuller's earth, which also appears under similar circumstances near Ryegate in Surrey. In this sand near Woburn also is found the wood-stone, consisting of wood petrified by hornstone.

§ 63. Not only does this sand appear with considerable regularity from Dorsetshire to the coast of Yorkshire, dipping eastward under the surface beneath the newer deposites, and also in Kent and Sussex; but likewise in the Isle of Wight, where it rises from beneath the blue marle and green sandstone underlying the central chalk range of the Isle. It there forms a considerable tract of comparatively low land on the south of that range, and between it and the chalk hills of the southern part of the island. It passes beneath the latter, appearing at the two extremes of the undercliff at Dunnose and Rocken End on the shore; and there is reason to suppose that it would also appear in the intermediate space, but for the immense ruin which covers it, owing, as is confidently believed, to the giving way of the blue marle overlying it (§ 59). It forms also the low tract south of the chalk range between Handfast point and Lulworth in Dorsetshire, and between it and the hills consisting of the Purbeck limestone.

CLUNCH CLAY.

§ 64. In some districts of England, indurated clay, when glossy, unctuous, and tending to a slaty texture, is called *Clunch*; when dull and smooth it is termed *Clod*. The term clunch clay is provincial.

This deposite, though but little is known of it, consists generally of various kinds of clays of different degrees of induration, which are often so calcareous as to form a coarse limestone; and they are sometimes aluminous, often bituminous and of a slaty texture.

Shales of the latter characters occur at the two extremities of this deposite. They are so highly aluminous on the northern coast near Whitby, and in some places in its neighbourhood, that extensive alum works have been established; and on the southern coast of England, namely in the Isle of Purbeck, the shale is so bituminous as to form a coaly matter of considerable extent near Kimmeridge, whence it is termed the Kimmeridge coal. This coal underlies the Portland stone in that island, (§ 68), giving colour to the belief, that the clunch clay (as well as the two succeeding deposites in respect of age, the Cornbrash limestone and the Forest marble) is one of the numerous beds of the oolite formation, of which the Portland stone is considered to be one of the uppermost beds. (See the order of superposition, &c. at the end of this volume).

The organic remains found in the clunch clay are belemnites, ammonites, and ostreæ. (Smith).

In the 3d volume of the Geological Transactions, there is a communication on the "Wolds of Lincolnshire, by Mr. Edward Bogg," by which it appears that the vast deposition of the shale of that country passes beneath an oolite; another cause for believing that the clunch clay, to which the shale of that country belongs, may be considered as a member of the oolite formation. This shale has been perforated to the depth of 300 feet without passing through it, and it consists of at least 40 beds chiefly of slaty clays, of different degrees of induration, some of which are inflammable, and some beds of grit-stone and iron-stone.

This stratum, near the northern coast, rises to the height of 780 feet above the sea, and has been penetrated to the depth of 300 feet below that level. It forms the lowlands of the vale of Bedford, and of the vale of the Isis, south of Oxford.

CORNBRASH LIMESTONE.

§ 65. The name of this limestone is provincial in Wiltshire. It commences with the preceding rock in the southern parts of Somersetshire, and reposing upon it, pursues an uninterrupted course, forming the high grounds in some parts of Oxfordshire and Buckinghamshire, to Olney; Bedford, and Peterborough in Northamptonshire, are both situated on it; and it occurs in spots higher north. It is a whitish, calcareous, and sandy rock, and is by some termed the Bedford limestone.

The organic remains it contains are, modiola, cardia, ostreæ, avicula, terebratulæ. (Smith).

FOREST MARBLE.

§ 66. This rock reposes immediately on the oolite. It occurs connected with one variety of it on the eastern side of the isle of Portland; and proceeds on the same side of the oolite, from the southern part of Somersetshire to Sleaford in Lincolnshire. The forest marble consists of thin beds of compact limestone alternating with a slaty clay, and is characterized by a large quantity of organic remains enclosed in it; these consist of pectines, teeth and bones, and wood (Smith).

By the order of superposition, &c. at the end of this volume, the reader will perceive that this and the two preceding strata—the Cornbrash limestone and the Clunch clay, are by its author considered to be members of the oolite formation. These beds are not noticed separately from that formation, from any doubt of the propriety of that order; but because no details of the whole formation have been published so as clearly to demonstrate its certainty.

OOLITE.

§ 67. This formation is extremely extensive; it proceeds from Somersetshire, with but slight interruption, to the banks of the Humber in Lincolnshire. The Portland stone, the Bath stone, and the Ketton stone, are rocks which to a common observer would appear to be absolutely distinct. They are nevertheless considered to be of the same formation; when carefully examined, all more or less present the same roe-like texture, which is characteristic of the oolite of Bath; and they all enclose a vast number of shells of the same kinds. These circumstances, together with their being found in the same geological position in reference to the accompanying rocks, determine their identity.

A variety of the oolite is also called the roe-stone, from the resemblance of the little round masses of which it consists to the roe of a fish; this is particularly obvious in the stone of which Bath is built. It is a very impure limestone, and will not burn into quick lime.

The oolite formation rises into hills of considerable elevation above the sea. A few miles west of Banbury it attains the height of 836 feet, at Monckton Farley near Bath 700; and at Sherborne in Dorsetshire 635 feet above the sea.

No geological details respecting the numerous beds of this extensive formation have yet been made public. On consulting the 'Order of Superposition,' &c. at the end of this volume, to which on this occasion the reader is especially referred, it will be seen that the Author, whose knowledge of the strata of England is commensurate with his indefatigable research, has included under the term Oolite formation, a very great number of beds, the existence of some of which would not be commonly known but for that interesting document. The Lias limestone, being occasionally, though rarely oolitic, is there included in the formation as being the lowermost bed of the whole series, which is divided into three parts, the upper, the middle, and the lower. In these also are included the three strata, of each of which a very slight notice has just been given; namely, the Forest marble, the Cornbrash limestone, and the clunch clay (Oxford Clay). So little indeed is generally known of this formation, that the only existing account of any of its beds, consists, I believe, in a notice of the Portland and Purbeck beds, the uppermost of the whole series, by T. Webster, in his letters to Sir Henry Englefield.

§ 68. The uppermost beds of the isle of Portland consist of an oolitic rock, and they are numerous. That which appears on the summit, and is called the Cap, is of a yellowish colour, and porcellanous character; it is only burnt for lime. The next bed is worked for sale, being the best building stone. Those below this bed contain numerous casts of shells that injure the stone, which is only used for coarser purposes; and with these beds alternate others consisting of chert. All these beds dip to the south, and rest upon the strata of argillaceous shale called Kimmeridge coal (§ 64); which occurs on the north-east cliff of Portland, near the sea. (W. p. 197.)

The Portland stone contains turritelles, ammonites, trigonia, pectines, and wood. (Smith).

§ 69. The stone of the Tilly Whim and Windspit quarries, on the coast of the isle of Purbeck, resembles the Portland oolite, and is called Purbeck Portland. These rocks have oolitic characters, are altogether calcareous, and consist of small grains or concretions adhering together; they are the only stones used for the fronts of public buildings in London. (W. p. 237.)

The quarries of Purbeck stone are on a range of hills extending across the island, south of the chalk range, and nearly parallel with it. The hill on which the quarries are situated, is composed of many beds, which generally dip to the north, passing under the ferruginous sand, consequently under the chalk; but they have suffered many dislocations and fractures. The Purbeck stone consists chiefly of shells, partly whole, and partly in a state of comminution, imbedded in a calcareous cement, which is sometimes very pure and crystallized, and sometimes in a state approaching to an indurated marle. These beds are separated by others entirely without shells; and also by layers of shale and marle, the shivery nature of which allows the stone to be quarried with much ease. It is thus obtained of various degrees of thickness, according to that of the bed, and the whole hill consists of many alternations of these strata. (W. 172.)

§ 70. It was long ago observed by Woodward, in his history of fossils, that the shells in the Purbeck marble consist chiefly of the Helix vivipara; and it is rather surprizing that this very ancient freshwater formation should not have excited more attention. Beautiful impressions of fish are frequently met with by the quarrymen between the laminæ of the limestone; and I saw abundance of fragments of bones, some of which belonged to the turtle. Complete fossil turtles have been found, and lately one extremely perfect. (W. p. 192).

LIAS.

§ 71. THE lias limestone reposes upon the red marle; between which and the oolite is commonly considered to be its geological situation. Some of its beds are occasionally oolitic, and being immediately in contact with those decidedly belonging to the oolite formation, the lias also is esteemed to belong to it by some geologists, among whom is the scientific author of the "Order of superposition of the strata of the British Islands," to be found at the end of this volume, to which the reader is referred.

Lias is composed chiefly of carbonate of lime, but it involves some silex, and small quantities of oxide of iron, carbon, bitumen, and water; it is tougher than common limestone, and when of a bluish-black, it is termed blue lias; when of a greyish or yellowish white colour, white lias. These two varieties alternate with each other, and generally in thin beds. They enclose ammonites and a great variety of other sea shells, and are remarkable for enclosing the remains of crocodiles at Lyme in Dorsetshire. It is the argillo-ferruginous limestone of some authors; the calp of Kirwan.

By the map it will be seen that this rock extends from a little to the west of Ilchester in Somersetshire by Bath and Gloucester, nearly through the center of the kingdom, and terminates a little beyond Lincoln. A few miles north of Gloucester it rises to the height of 1134 feet above the sea.

The organic remains which it encloses are numerous. Pentacrinites, ammonites, plagiostoma, ostreæ, and bones. (Smith.)

Beds of a rock which has the same mineralogical, or rather chemical characters as the lias, are sometimes found in mountain limestone, but as these beds do not contain the same organic remains as the lias, they are not esteemed to belong to the same formation.

The lias burns into a very strong quick lime, valuable when made into mortar for its increasing hardness under water. It was therefore employed in constructing the Edystone lighthouse.

Hitherto, however the lias has not received that attention which it merits from its having been employed, chiefly in other countries, in that valuable discovery of modern times, the Lithographic art, which promises to be of vast utility in science. The geological position of this rock constitutes the chief part of our knowledge respecting it. There is, I believe, no general description of the long range of hills already adverted to; and the only particular description that has been given relates to the occurrence of this rock in Somersetshire.

§ 72. At Redland, near Bristol, the basset edges of the mountain limestone are covered by a sandstone, on which reposes a limestone having all the characters of the lias. It lies in thin horizontal layers, containing ammonites, gryphites, and anomiæ in abundance: it extends to Cotham, where some of the strata are remarkable for taking a beautiful polish, and are known by the name of the Cotham stone. (G. T. vol. iv. p. 196).

§ 73. This rock is found on the coast of Somersetshire bordering the Bristol Channel, and for some little distance inland; being in all probability a continuation on the west, of the Polden hills, which are south-west of Glastonbury, and which consist chiefly of the lias. Its extreme point on the west is a short distance beyond Watchet, but it is the principal barrier to the sea for several miles eastward of that place, in the form of cliffs which in some places are 100 feet high. It is of a dull earthy aspect, with a large conchoidal fracture, and generally of a light slate blue colour. It occurs in very regular strata which seldom exceed a foot in thickness, and are often not more than four inches. These strata are separated from each other by others of slate-clay varying considerably in thickness. The clay is grey, brown or black, and is frequently bituminous, and readily divides into laminæ as thin as common pasteboard. This clay encloses large ammonites, of which the beautiful irridescence of the nacre is preserved; but the lias itself contains but few organic remains. In several places it has been observed that each bed of the lias is not of one continuous mass, but that it lies in the bed in columnar concretions which are distinct, and resemble in respect of form, the masses of basalt composing the Giant's Causeway on the coast of Antrim. These masses are sometimes divided into septa which are coated with calcareous spar and sulphate of strontian, and sometimes enclose the latter in a state of very perfect crystallization. In several places along the coast, the lias has the appearance of being interstratified with the red marle; but this is considered to be owing to the curvatures and dislocations of the strata every where manifest along the coast, particularly along that part of it which consists of greywacké, on which the red marle and the lias rest. (G. T. vol. iii. p. 367 & seq.)

RED MARLE.

§ 74. This deposite is by some also termed the *New Red Sandstone*, *Red Rock*, or *Red Ground*. It is a very extensive deposite, extending with little interruption from the northern bank of the Tees in Durham to the southern coast of Devonshire. Its texture is very various. It appears sometimes as a reddish marle or clay, sometimes as a sandstone; sometimes the clay and sandstone are interstratified or pass the one into the other; and it will appear that it is associated with, or contains beds of, a conglomerate consisting of masses of different rocks cemented by marle or by sand. When this deposite appears as a sandstone, its characters differ greatly in different places; it is occasionally calcareous, and sometimes of a slaty texture. Above all, this extensive deposite is remarkable for containing masses or beds of gypsum; and the great rock-salt formation of England occurs within it, or is subordinate to it; in some places the strata of coal dip beneath it.

The red marle does not rise into hills of any considerable elevation; they are on the contrary generally low, and with rounded outlines. Many tracts occupied by it are very flat. In the central parts of England, the Severn traverses it for a considerable length; and in the northern, the Ouse and the Trent, streams tributary to the Humber, taking a long course through its plains.

§ 75. In the south-eastern parts of Durham, it appears as a fine grained sandstone of a brick-red colour, which effervesces with acids; its limit on the north-east is a little above the northern bank of the Tees. The strata are numerous, and consist (as far as one can judge from the miner's language) of white, grey, or red sandstone, with occasional interposed strata of a more compact nature, red or blue shale (slate clay), coaly matter in thin layers, and gypsum in nodules and in beds of from one to three feet in thickness. The lowest bed in two of the deepest workings, was a white rock of a calcareous nature. (G. T. vol. iv. p. 2.)

§ 76. A sandstone covers a great plain in Westmoreland, on the west of the range of mountains of which Cross Fell is the highest, and which is near the south-western extremity of the great Newcastle coal-field. This plain is of considerable breadth north of Carlisle. Its west and south-west boundary are the coal measures south of Carlisle, which repose on mountain limestone, resting on the slaty mountains of Cumberland (Plate 2, fig. 4.) This sandstone encloses gypsum in many places on the banks of the Eden and Petteril, and in the great valley of Carlisle.

Near Whitehaven, the upper beds of the coal measures lie beneath a stratum of magnesian limestone, which, together with the beds of coal, passes beneath the red sandstone (Pl. 2, fig. 4.) In the lowest part of the latter stratum there is a gypsum quarry, whence it is concluded that this sandstone is of the same date as that of the vales of Cheshire, Salop, Lancashire, and York; the matrix of our great quarries of gypsum and rock salt; and a deposition more recent than the magnesian limestone which is incumbent on the upper strata of the principal English coal-fields. The sandstone of this plain abuts against a range of greenstone (Plate 2, fig. 4) some miles north-east of Penrith in Cumberland. The greenstone may be traced for several miles, and rises into those elevations termed Dufton pike and Knock pike. (G. T. vol. iv. p. 105, 116.)

§ 77. The southern parts of Lancashire, the northern extremity of Shropshire, and the whole of the intervening county of Cheshire, form in conjunction one vast tract of plain country, interrupted by few elevations, and these inconsiderable in size and extent. That part of this great plain which is nearest to the great deposite of *rock-salt*,* is irregularly formed by ridges of limestone and calcareous sandstone; and the whole tract above mentioned consists chiefly of sandstone, belonging to the extensive deposite now under consideration. (G. T. vol. i. p. 39.)

§ 78. In Worcestershire, the same rock, though differing slightly in its characters, is found in the neighbourhood of the *brine springs* of that county. The prevailing rock around Droitwich is a fine grained calcareo-agillaceous sandstone, of a brownish red colour, with occasional patches and spots which are greenish blue. At Doder hill, where a vertical section of it is exposed, it contains beds of a greenish grey colour, and of a more indurated texture, but which do not appear to differ materially in composition from the red sandstone. These contain slender veins of crystallized gypsum, the forms of which are very distinct where the widening of the vein has produced small cavities. (G. T. v. ii. p. 95.) But around Worcester it sometimes resembles mere marle, with occasional patches of a blue or of a green colour; sometimes a fine sandstone and sometimes a breccia. (K. 110.) In various parts of Worcestershire, there are alternations of this marle with small and large grained gritstones. (K. 109.)

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* Some account of the Cheshire salt deposite is given in my 'Outlines of Mineralogy and Geology'; but the reader is referred to a more extended description by Dr. Holland in the first volume of the Transactions of the Geological Society.

§ 79. In Derbyshire, and some parts of Cheshire, the strata composing the red marle are very nearly horizontal; in a few places only have they any considerable dip, which then does not appear to be regularly in one direction. In some of the hills and vales of Derbyshire, are visible some fine-grained micaceous *gritstone* beds, of considerable thickness, which occasionally are sandy, as at Normaton, south of Derby, &c. From the more clayey parts of this stratum, bricks and tiles are made. Occasionally it encloses streaks, or thin beds, of light blue or greenish blue earth, or marle. These are common in the red marle of Nottinghamshire.

In Derbyshire, some considerable deposites of gypsum have been found in the red marle, and some of them are worked for that mineral. Chellaston is about five or six miles south-east of Derby, and it appears that on the south-east of that town there are several quarries: part of Chellaston hill would present a naked and waterworn rock of gypsum, were it not for the alluvial clay that covers it. Near Aston also, which is somewhat further on the south-east, and formerly at Ballington hill near Ambaston, there were other quarries: gypsum has also been seen in other places. It should seem that it occurs only in particular patches or nodules, where it occasions a rise or isolated hill, by the additional thickness which it gives to the stratum of marle in those places; but it occasionally forms very thin beds or layers, which sometimes are finely striated transversely to the strata. The principal demand for the pure white gypsum, or that slightly streaked with red, is by the potters in Staffordshire, who form their molds of the plaster of Paris which it yields; but some particular blocks are selected for the use of the turner, and the maker of alabaster ornaments. When mixed with blue or green earth, it is called flooring-stone; that which is found in very thin beds, is used for the building of walls and other common purposes. (F. 148, & seq.)

§ 80. Gypsum is also found in the red marle in several places in Nottinghamshire and Staffordshire. (F. 151).

§ 81. The lower part of Bristol is built on this deposite; but on the north-western side of that city, other strata arise from under it, which are composed of various kinds of limestones containing organic remains, and marles, clays, and ironstones. These strata are parallel, and rise at about the angle of 45 degrees into hills of considerable height; as at Clifton,* just beyond which the limestone appears on both sides of the river (§ 140). At the termination of these rocks towards the Severn, the old red sandstone is described as rising from beneath them; beyond which (Plate 2, fig. 3) the red marle or sandstone occurs again in parallel and nearly horizontal strata of a red and yellow colour. In some places near Bristol, the lower part of the sandstone alternates with layers of a blue or greenish colour, abounding in sulphate of strontian, the masses of which contain crystals of the same substance of an opake white, or of a dull red colour. A small quantity of sulphate of barytes also occurs in the sandstone. In the low ground on which great part of Bristol is built, hollows occur in the surface of the sandstone, which are filled with alluvial matter, such as clay, of a blue colour, containing phosphate of iron, peat, &c. In this alluvial matter the horns and teeth of deer, the grinders of the boar, and nuts have been found. On digging the channel of the New River, a bed of peat was found 12 or 14 feet beneath the surface, and more than two feet thick; on the top of this were a number of oak trees, tolerably sound, and all lying in the same direction. (G. T. vol. iv. p. 194).

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* Great part of Clifton is built upon a siliceous ironstone, which also is found in the country south of the Avon. It is in the cavities of this rock that the beautiful quartz crystals, called Bristol stones, are found. They commonly occur in six-sided prisms terminated by six-sided pyramids; but quartz in the form

On the top of the limestone strata forming the cliffs on each side of the Avon, lies a yellowish sandstone, which has sometimes the appearance of a breccia. In its fissure are found crystals of carbonate of lime and of sulphate of strontian, the latter often in a radiated form, and sometimes in balls weighing many pounds. At Redland this sandstone is covered by the lias limestone in

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of the primitive rhomboid has been found here, though rarely. Three beds of coal are found beneath this iron sandstone, near the Hot well house, upon the banks of the river. The coal lies upon the limestone above noticed. (G. T. vol. iv. p. 195).

horizontal strata, containing ammonites, gryphites, and anomiæ in abundance. (G. T. vol. iv. p. 196.)

The red clay belonging to this formation, contains, in the neighbourhood of Bristol, not only gypsum, but it also abounds with sulphate of strontian in the form of veins and even large beds. (G. T. vol. iv. p.214.)

§ 82. The hills of greywacké in Somersetshire (§ 157) are surrounded, either by a conglomerate, or by a red sandstone, sometimes tolerably compact, but more frequently of a friable texture. These conglomerates and sandstones assume very various appearances, but under every form of aggregation the same materials may be traced. Where the component parts are large, as in the conglomerates, the nodules consist of some varieties of the rocks that compose the greywacké formation; in many places there are nodules of a limestone very similar to that of the beds enclosed in the greywacké, and which therefore are considered as *subordinate* to that formation. The conglomerates and sandstones are found in all the intervening vallies, and the great valley on the western side of the Quantock hills is wholly composed of them. They are not however confined to the vallies, but are sometimes found on the sides of the hills, at a very considerable elevation; (G. T. vol. iii. p. 356) and even so high as near the summit of the Quantock range, where rounded fragments of greywacké; cemented by a deep red clay, form a mass of extreme hardness. (p. 361).

By this description of these deposites it appears that they have both, in this neighbourhood, resulted from the ruin of the greywacké formation, since they not only enclose fragments of it, but also of the limestone imbedded in it, and the fragments are sometimes rounded. In some places, the quantity of calcareous matter in the conglomerate is so great that it is quarried for the purpose of obtaining lime from it. In other places, it is almost entirely siliceous. In another, it contained the green carbonate and sulphuret of copper. The sandstone, at least, may be considered as a member of the numerous series of rocks constituting what is commonly called the red marle, sometimes the red rock. Near Timberscombe the conglomerate is covered by a friable red marly sandstone(G. T. vol. iii. p. 359). The rich vale of Taunton Dean is believed to consist of rocks of this description.

In some places, where the argillaceous sandstone is red, and contains a variable proportion of calcareous matter, it also contains spots and stripes of a greenish colour, and it is occasionally variegated with yellow, and contains no fragments. (G. T. vol. iii. p. 364.) The latter character renders it probable that this formation may be analogous to the variegated, or second sandstone formation of Werner, which is 'marked with yellow green, brown, red, and white stripes, and layers of different coloured sandstone alternating with one another.'

Not far from Watchet, on the coast of Somersetshire, bordering the Bristol Channel, the red marle is of a bright brick red colour, very friable, and traversed in every direction from top to bottom, by pure white veins of gypsum, which seem to identify it with the formation covering the Cheshire rock-salt formation, but no traces of salt were visible. (G. T. vol. iii. p. 377.)

§ 83. In the cliffs about half way between Sidmouth and Seaton in Devonshire, the red marle contains gypsum, very much resembling the mineral called mountain leather; nor was it difficult to trace on the spot, the gradual transition of the transparent crystalline gypsum into this amianthiform state. (K. 106). The red cliffs of Budleigh Salterton near Teignmouth, which are of considerable height, and those also of Teignmouth itself, consist of alternations of argillaceous beds of sandstone and of breccia (conglomerate) and the red strata on the opposite side, near Powderham, are alternately soft and stony, but always intermixed more or less with strata of breccia; and they are inclined in various directions. (K. 109).

MAGNESIAN LIMESTONE.

§ 84. This limestone, which has obtained the name of Magnesian, from its containing about 20 per cent. of carbonate of magnesia, prevails considerably in England. The principal range of hills consisting of it, extends from Sunderland on the north-east coast, to Nottingham. This range is not very elevated; near its northern and southern terminations it attains the height of about 600 feet above the sea, but the middle part is not so high, and the hills of which the chain is constituted are round topped. It is ascertained that the geological situation of this limestone is above the coal formation, inasmuch as some of the beds of the Newcastle and Whitehaven deposites have been worked beneath it (§ 87, 89), as well as those of Derbyshire (§ 90).

This limestone also occurs in beds in mountain limestone (§ 92, 133). It differs from common limestone in external character, in having generally a granular sandy structure, a glimmering lustre, and a yellow colour; and in the course of the range from Nottingham northwards, its surface in many places is covered by a poor herbage, uncommon to limestone, attributable to the magnesia it contains, which is known to be unfavourable to vegetation.

The organic remains inclosed in the magnesian limestone are, madreporæ, encrini, and producti. (Smith.)

§ 85. The magnesian limestone constituting the range above alluded to, occurs in beds dipping gently towards the south-east (Ann. dec. 1814) and passing beneath the red marle or new red sandstone, or occasionally alternating with it. These circumstances evince an intimate connection between the red marle and the magnesian limestone. In many parts of England this is shewn by the existence of a rock which is termed a *breccia*, which in some places consists of angular fragments of limestone and sandstone, cemented together by magnesian carbonate of lime. A breccia of this kind is found on the Mendip hills, near to the celebrated cliffs of Cheddar. A similar rock is found near Cowbridge in Wales, and at Caerdeston, and Loton, and other places in Shropshire. A breccia, differing from it only in containing rounded masses of quartz, is found lying on the western basset edges of the highly inclined strata of mountain limestone forming the ridge between Bristol and the Severn. It extends along the limestone for a considerable distance north and south of the Avon, and alternates with the red marle (G. T. vol. iv. p. 202 & seq.), of which it is considered to be the lowest stratum. (p. 212.)

§ 86. Magnesian limestone, exactly at the northern extremity of its western boundary, overlies the coal strata in the cliffs at Cullercoats in Northumberland. (G. T. vol. iv. p. 3.) It overlies the 90 fathom dyke, which appears between the strata of coal in a nearly vertical position; and it is concluded that the magnesian limestone is of a newer formation than the coal and the dyke, since the dyke has injured the coal (§ 123) but has not affected the limestone. This rock, along the coast of Durham, is covered by a species of breccia, the cement of which is a marle-like substance consisting chiefly of magnesian carbonate of lime; and with this breccia the wide chasms or interruptions in the cliff are filled. The upper strata of the limestone are thin and slaty, and inclining to a buff colour. Below, the stratification is less distinct, and the colour is hair brown, the texture crystalline and cellular: a variety that is flexible has lately been found. It partakes of the nature of swinestone; and from containing some inflammable matter, it requires only a small quantity of coal to reduce it to lime. (G. T. vol. iv. p. 6.)

§ 87. It is well ascertained that the magnesian limestone of Durham and Northumberland rests upon the coal measures; for at Pallion, a little to the west of Sunderland, and but a short distance from the western limit of the magnesian limestone, it was only 12 fathoms thick, and was found to overlie the coal strata, which were bored through to the depth of 140 fathoms, without finding a seam of coal worth working. No coal mine has yet been won by sinking a shaft through the limestone, although the workings of some collieries, situated on its western boundary, have been carried underneath it. At Hart, near Hartlepool, which is almost the southern extremity of the limestone on that coast, it was bored to the depth of 52 fathoms, without penetrating through it. (G. T. vol. iv. p. 8.)

§ 87*. The dip of the coal strata south of Newcastle is not in conformity with that of the magnesian limestone. It is a circumstance, however, too well ascertained to admit of a doubt, though difficult to be accounted for, that the coal is deteriorated in quality where it is covered by the limestone. (G. T. vol. iv. p. 9.) Botryoidal masses of fetid limestone devoid of magnesia, in balls varying from the size of a pea to two feet in diameter, imbedded in a soft, marly, magnesian limestone, are found at Hartlepool, in a quarry at Building hill near Sunderland, and on the sea-coast a mile or two north of Monk Wearmouth. These balls are radiated from the centre, their colour hair brown, fracture shining, cross fracture splendent approaching to vitreous; white calcareous spar is often observed in them. The magnesian limestone of this district contains few organic remains. A representation of a fish found in it is given in the 4th volume of the Geological Transactions. It contains but few shells. (G. T. vol. iv. p. 10.)

§ 88. The beds constituting this range, are described as being about 300 feet in thickness, on the east of the coal-field in Derbyshire, which is near its southern extremity. Their general colour is yellow, which is often as bright as gamboge, with almost all intermediate shades, to a very light straw, and white. Many of the beds have a granular texture, and a brown or reddish hue, particularly near their joints. Those beds in which the magnesian earth abounds most, generally pass for a grit-stone. A considerable number of the upper beds are incapable of calcination. At Dudley, Walsall, and other distant places, where these strata appear, they are called clunch, mudstone, &c. and perish on exposure; but towards the bottom of this series, several beds of compact blue limestone are found imbedded in blue clay. These abound in anomia and other shells, and some of them differ greatly in composition from the magnesian limestone, upon which they are used as a manure after calcination. The whole series of these beds are of remarkable regularity, and have an easy dip towards the east. (F. p. 158.)

§ 89. The coal strata near Whitehaven on the north-western coast, also pass beneath magnesian limestone. (G. T. vol. iv. p. 105.) (See Pl. 2. fig. 4.)

§. 90. The coal beds of the Derbyshire field extend beneath the magnesian limestone, and have been worked under it at Bilborough and Nuthall, which are situated on it, a few miles north-west of Nottingham; (F. 166.) and all the coal strata on the east of the great zig-gag *fault*, (§ 125), from Trowel in Nottinghamshire, to the north of North Aston in Yorkshire, have an easy dip to the east, similar to that of the magnesian limestone, (F. 168), and being worked in several places beneath that limestone, probably pass beneath it with the same gentle dip.

§ 91. This limestone also appears south of the range of hills terminating near Nottingham, in connexion with the slates of Charnwood forest on the north and north-eastern border of the Ashby de la Zouch coal-field. Breedon hill, and some other hills appear on the west of Ashby de la Zouch; they consist of the magnesian limestone in nearly vertical strata (F. 158), which, considering that the beds in the long range north of Nottingham have only a gentle dip to the east, may perhaps be owing to some subsidence in their neighbourhood.

§ 92. Magnesian limestone occurs interstratified with mountain limestone in a hill overlooking Blais castle near Bristol; and a small ridge of rock, about four miles north-west of Bristol, upon which Lord de Clifford's house is built, is entirely composed of the same limestone, abounding in shells and madrepores. (G. T. vol. iv. p. 215.) It is also found at Redland not far from Bristol, in horizontal strata lying on a yellowish sand covering the basset edges of the inclined strata of limestone on each side the Avon.

COAL.

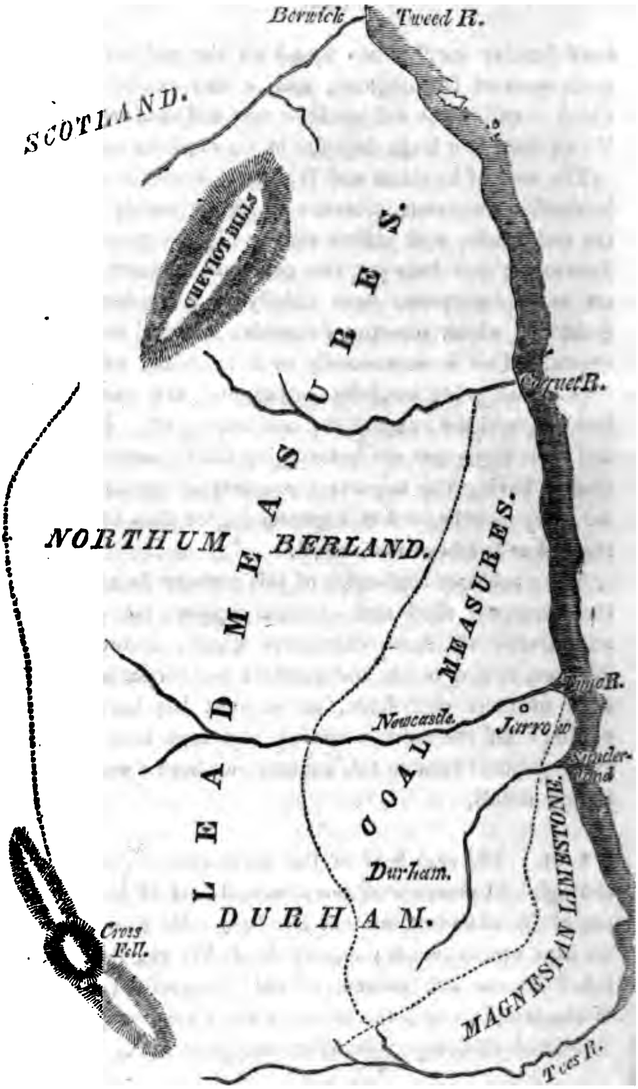
§ 93. The *Coal-fields* of our country, as they are expressively termed in Geological language, are numerous; and they are highly important to us, inasmuch as they afford some of the most essential domestic enjoyments of civilized life: for peopled and cultivated as England is, and therefore possessing but few and small forests, the comforts of its inhabitants are greatly augmented by, and may be said to depend in great measure upon, its inexhaustible deposites of coal.

One of the nearest to London of these, is the most southern deposite in England; namely, the small one lying at the north-eastern termination of the Mendip hills in Somersetshire, which are of mountain limestone. Two or three small patches occur on the north of that point, and between it and the more considerable deposite of Kingswood and Micklewood near Bristol; to the north-west of which, and on the other side of the Severn, is found the coal of the forest of Dean. Coal again occurs near Stourport in Worcestershire; whence it ranges in a direction nearly north, and with little interruption, to Chester, and beyond it on both banks of the Dee. An immense deposite, of which the southern-most point is near Nottingham, ranges through Derbyshire, Yorkshire, Durham, and Northumberland, quite to the Tweed: in this long range the coal is not absolutely connected, but the interruptions are not considerable; again, abundance is found at Whitehaven on the north-western side of England. Besides the foregoing, many comparatively small insular patches are found on the north-east and north-west of Birmingham, and in that extensive tract which is called the red marle or new red sandstone. In Wales there is a large deposite on its southern coast.

The coal of England and Wales, it is worthy of note, is found in numerous instances *within*, or passing *beneath* the red marle, and almost universally *above* mountain limestone; but between the coal and limestone there are some interposed beds chiefly of a sandstone, or gritstone, which sometimes contains rounded masses of quartz. This is occasionally of a character which allows of its being used for mill-stones, and has therefore received the name of the *mill-stone-grit*. Its chief and most important use is for lining the furnaces of iron works, having the important property of enduring heat for many months, and to a greater degree than any other stone that has been discovered.

The numerous coal-fields of this country do not all of them however yield coal of equal quality; nor do they all partake of those characters which, according to Werner, belong to the independent coal formation. Of some of these coal-fields, no account has been made public. Of the most extensive, and most beneficial in every point of view to this country, we have a very satisfactory detail.

§ 94. The coal-field of the north-eastern extremity of England extends over the principal part of the counties of *Northumberland and Durham*. Of this district we have two accounts; one by N. J. Winch, Esq. published in the 4th volume of the Transactions of the Geological Society; the other by Dr. Thompson, in the Annals of Philosophy for Nov. and Dec. 1814. I pro-


Berwick
Tweed R.
SCOTLAND.
CHEVIOT HILLS
LEAD MEASURES.
NORTHUMBERLAND.
Coquet R.
COAL MEASURES.
Tyne R.
Newcastle.
Jarrow
Sunderland
MAGNESIAN LIMESTONE.
Durham.
DURHAM.
Cross Fell.
Tees R.

ceed to select from both, recommending them, and particularly the former, to the perusal of the reader afterwards. This part of England is highly interesting both in a geological and economical point of view. Geological, since the facts it discloses are extremely curious; and economical since it supplies London, and the east and south coasts of England with coal, besides what is consumed by the inhabitants themselves; and since the quantity of lead which it annually yields is scarcely inferior to what is furnished by all the rest of Europe.

§ 95. This great coal-field may be said to be included within a kind of triangle, having its apex at Berwick upon Tweed, and its base upon the river Tees, which separates Durham from Yorkshire (see the opposite sketch.) From Berwick to the mouth of the Tees along the coast is about 80 miles; and on this side of the triangle, the country is generally low; but it rises as we recede from the sea, until we arrive at the top of Cross Fell, which is one of the highest mountains in England, being 2901 feet above the level of the sea; yet so gentle and gradual is the elevation as we ascend its eastern side from the coast, that one may ride on horseback to the very summit. On the western side, Cross Fell rises abruptly from the vale of Eden in Westmoreland and Cumberland. (Pl. 2, fig. 4.)

§ 96. The *whole tract* consists of a series of beds, amounting to the number of 229, confounding together several smaller ones composed nearly of the same material. They consist of five different substances, some of which alternate with each other several times; namely, *coal*, *sandstone*, *slate-clay* or *shale*, *limestone*, and *basalt*.

The whole country comprehended within the triangle, according to Dr. Thompson, possesses the characters of the *Independent Coal formation.*

All the beds of coal dip towards the east; so that the lowest of them, which near the coast is far below the level of the sea, rises out *to day* at Cross Fell. (Plate 2, fig. 4.) It is a bed of imperfect coal, called by the country people *Crow coal;* and as it does not burn by itself, it is made up into balls with clay, and then used as a fuel. This bed is found near the summit of Cross Fell, but as it dips down towards the east, it is calculated to lie 387 fathoms below the lowest of the Newcastle beds, a little on the east of that town.

This tract however has been divided by each of the fore-mentioned authors into two separate formations. By the former of them into *Lead measures* and *Coal measures*, which are, I believe, provincial terms; and by the latter into the *Independent Coal formation* and the *Newcastle Coal formation.*

§ 97. The tract, termed the *Lead measures*, extends from Berwick on the north, to the Tees on the south (see sketch, p. 88); its northern part is bounded by the sea on the east, and by the Cheviot hills on the west; and its southern part, by the coal measures on the east, and a range of high land, of which Cross Fell is the apex, on the west.* This district has been termed the Lead measures, chiefly because veins of lead abound in a particular part of it.

* The range of hills of which Cross Fell is the highest point, consist of about 20 beds of limestone, alternating with about 50 beds of sandstone, 80 of shale, a few thin beds of coal, and one of basalt (trap?); and are in the whole 2749 feet thick. The whole

§ 98. The *Coal measures* commence near the river Coquet on the north, and extend nearly to the Tees on the south : the length of this tract is about 58 miles, and its greatest breadth about 24. The strata of the Lead measures pass under those of the Coal measures (Pl. 2, fig. 4.); which latter pass beneath the magnesian limestone (§ 87); the northernmost point of which is near the mouth of the river Tyne. (See sketch, p. 88.)

§ 99. It is requisite that some reasons should here be shewn for the cause of this division into two formations, since they both yield coal in a greater or less degree; whence we might incline to consider the whole as being *one formation.* But it must be observed, that in the strata constituting the Coal measures, the *organic remains belong exclusively to fresh water*; while in the strata of the Lead measures, both sandstone and limestone are found containing *marine shells, or impressions of them.*

§ 100. *The organic remains found in the strata of the Lead measures*, are, in the limestone, madrepores, millepores, encrinites, pectinites, large oyster and other bivalve shells. In the shale, encrinites, pectinites, and small muscle shells. In the sandstone, impressions of pectinites, arcæ, anomiæ, and euphorbiæ.

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of these beds are considered as belonging to the mountain limestone formation. The lowest of them crop out on these hills, and are visible on the escarpment of their western side. The fundamental rock of these strata is *greywacké slate*, but they do not rest upon it, since a stratum of the *old red sandstone* lies between them and the slate. (See G. T. vol. iv. p. 105 & seq. and Plate 2, fig. 4.)

§ 101. *The organic remains found in the Coal strata are*—In the shale, the impressions of several plants, amongst which is a variety of fern. Another fern or two is found in the nodules of clay-ironstone, as well as impressions of cones. Impressions of the bark of a plant resembling euphorbia, in iron pyrites, are found in several collieries; of another plant in coal: vegetable impressions in sandstone: the cast of a cane-like vegetable: an aggregate of black quartz crystals diverging from the center, having the interstices filled with yellow ochre; it is supposed to be a mineralized tree, and is found at Bigge's main colliery, and often in large masses on the sea-shore. Bivalve shells, like those of the freshwater muscle, in dark grey ironstone, and in black shale and ironstone: the same in black shale in Hebburn colliery, at the depth of 780 feet.

Amongst these there are *no marine fossils*, and there is reason to believe that no organic remains of marine origin have ever been discovered in the strata belonging to the tract termed the Coal measures.

§ 102. Hence it seems evident that the whole district may correctly be divided into two formations, although it may not be easy to decide where the one begins and the other ends. It is however asserted, that when the *mill-stone grit* (a coarse-grained sandstone so called) and the blue *encrinal limestone* are seen cropping out, one may then be sure that the *boundary of the Coal formation is passed.* The places where these strata crop out, have not been noted in the observations of the two authors from whose accounts this is chiefly extracted; but as they agree in determining the boundary of the Coal measures to be nearly in the direction of the dotted line separating them from the Lead measures in the sketch at page 88, and extending from the Coquet to the Tees, we may suppose these strata to appear on the surface along that line.

It is therefore clear from the facts which have been observed that the whole Coal-field is properly divisible into *two Formations.* It appears to me however that, instead of considering each formation by itself, we shall find advantage in giving our attention separately to each of the several substances forming the beds of the whole district. These are, *Coal*, *Sandstone*, *Slate-Clay*, *Limestone*, and *Basalt;* after which we may complete the view of the whole Coal-field, by noticing the nature of the *Veins* which traverse or intersect it; these are filled either by *Lead*, *Basalt*, or *Sandstone.*

In the view that we are about to take of the beds composing this district, we shall have occasion to distinguish between such as appear in the two formations. These have been termed *Coal measures* and *Lead measures*, to which terms I shall adhere.

§ 103. The inequality of the surface does not affect the dip or inclination of the strata constituting the *Coal measures*; so that when they are interrupted or cut off by the intervention of a valley, they will be found on the sides of the opposite hills at the same levels, as if the beds had once been continuous. The conclusion is obvious, that the present irregularities of hill and dale have been occasioned by the partial destruction or dispersion of the uppermost strata constituting the coal formation.

The beds of coal and of the other strata composing the *Coal measures*, are not every where of uniform thickness.

They occasionally enlarge or contract so greatly, that it is only by an extensive comparison of the whole series, that any certainty is arrived at of that general uniformity of stratification which is known actually to exist. From the best information, they are calculated at 1620 feet in thickness; and the strata composing the *Lead measures*, which are pretty regular, and which pass beneath, or underlie the Coal measures, are estimated at 2749 feet.

§ 104. The beds of coal, &c. basset out at the surface one after the other; each on the *east* of that which immediately precedes it in point of age. These beds are sometimes visible; but are more commonly covered by alluvial soil. We shall therefore begin by some notice of the

Alluvium.

The alluvium contains masses of different rocks composing the whole district; and amongst them, portions of hard black *basalt* are found every where in abundance. From this stone, the ancient inhabitants of Britain formed the heads of their battle-axes, which are commonly called celts. They resemble in shape the tomahawks found in the South Sea islands. Barbed arrow heads, neatly finished, and made of pale-coloured flint, are frequently picked up on the moors, and are called *elf-bolts*. It also contains portions of the trap rocks of the Cheviot range, and masses of fine-grained granite appear on the surface of the whole country.

In the Coal measures, *potters' clay* occurs immediately below the vegetable soil. Its colour is bluish or smoke-grey, and sometimes yellow approaching to orange, in consequence of a mixture of iron ochre. It is used in the manufacture of coarse earthen-ware, bricks, and tiles.

Coal.

§ 105. We shall begin with the coal of the *Lead measures*, as being the older formation of the two, composing the whole coal-field. The number of beds of coal in this formation does not appear to have been precisely ascertained. Dr. Thompson mentions only seven, of which only four exceed three or four feet in thickness, and consist of a slate-coal similar to the Scotch, Welch, or Staffordshire coal, and do not cake. The coal mines are very numerous between Berwick and the Coquet river; (see sketch). South of that river, there are but few mines in the tract termed the lead-measures, and the coal is very inferior in quality to that of the mines north of the Coquet. These mines are very shallow, and it is remarkable that the beds of coal, and the strata between which they lie, *undulate with the surface of the country*, which is not the case in the coal-measures. North of the Coquet, therefore, the strata are not very regular, and there is so little agreement between the strata there, and the strata in the district where the lead is principally found (about twenty miles west of Durham), that it is doubtful whether the two districts are properly classed together under the term lead-measures.

§ 106. The strata of every Independent Coal formation dip from the surface, and rise again to it after attaining a certain depth; so that a section of them gives the idea of a form of a boat. A place called Jarrow (see sketch, p. 88), which is about five miles from the mouth of the Tyne, and on its southern bank, is the spot beneath which the beds of *Coal in the Coal measures*, are found at their greatest depth. One of the thickest beds, called the High Main (§ 108), is 960 feet below the grass at Jarrow, and rises on all sides; but as the dip of the strata (which averages 1 inch in 20) is not uniform in every part in the surrounding district, that bed does not rise to the surface at equal distances around that place.

We may assume that Jarrow in the center* of the Coal measures, since it is the spot beneath which the *High Main* coal is found at the greatest depth beneath the surface. There is a considerable though not a perfect uniformity in the distance of the several coal beds from each other. Hence, as the High Main coal rises to the surface or the alluvial soil, around Jarrow, we may conclude that the beds of coal above and below the High Main, arise also, at a distance from it, proportionate to their depth beneath it.

§ 107. The whole surface of the coal measures is calculated at 180 square miles. The greatest number of the numerous mines are situated on both sides the river Tyne, but are not far distant from its banks. There are several in the northern part of the district, and many about five miles south of the Tyne, about mid-way between Newcastle and Durham.

§ 108. In the coal measures forty beds of coal have been seen; but a considerable number of these are insignificant in point of thickness. The two most important beds are those distinguished by the names of

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* In forming this conclusion, it is necessarily inferred that the Coal measures once extended far to the east of the present Coast of Durham, and *above* the level of the sea: that they exist *beneath* it, is proved by the workings under it.

High main and *Low main*. The thickness of the first is six feet, of the second six feet six inches. The High main is about 60 fathoms above the Low main coal, which latter is at St. Anthon's colliery, not far from Newcastle, 135 fathoms from the surface. Between them occur eight beds of coal, one of which is four feet thick, another is three feet thick. Seven beds have been seen under the Low main, but the quality is inferior, and more nearly approaches that of the coal in the Lead measures.

The coal of the district termed the Lead measures, is therefore very far inferior in quantity to that of the Coal measures. The superior excellence of the coal of the latter formation in quality, over every other, is sufficiently known. The quantity of coal raised annually in this district, and sent to London, and the whole east and south coasts of Great Britain, is quite enormous. Shields and Sunderland are the two places from which they are exported; and a curious distribution of the trade has taken place, depending upon the size of the two rivers. The Tyne vessels are large, and are therefore chiefly destined for the London market. The Wear vessels, on the contrary, are so small, that they can make their way into the small rivers and harbours all over the kingdom, and therefore they supply the whole east and south coasts as far west as Plymouth.

To form an idea, says Dr. Thomson, of the quantity of coal contained in the formation called the Coal measures, let us suppose it to extend in length from north to south 23 miles, and that its average breadth is eight miles. This makes a surface amounting to rather more than 180 square miles, or 557,568,000 square yards. The utmost thickness of all the beds of coal put together does not exceed 44 feet; but there are eleven beds not workable, the thickness of each amounting only to a few inches. If they be deducted, the amount of the rest will be 36 feet or 12 yards. Perhaps five of the other beds likewise should be struck off, as they amount altogether only to six feet, and therefore at present are not considered as worth working. The remainder will be ten yards; so that the whole coal in this formation amounts to 5,575,680 cubic yards. How much of this is already removed by mining I do not know, but the Newcastle collieries have been wrought for so many years to an enormous extent, that the quantity already mined must be considerable. I conceive the quantity of coal exported yearly from this formation exceeds two millions of chaldrons; for the county of Durham alone exports 1⅓ millions. A chaldron weighs 1.4 ton; so that 2.8 millions of tons of coal are annually raised in these counties out of this formation. Now a ton of coal is very nearly one cubic yard; so that the yearly loss from mining amounts to 2.8 millions, or (adding a third for waste) to 3.7 millions of yards. According to this statement, the Newcastle coals may be mined to the present extent for 1500 years before they be exhausted. But from this number we must deduct the amount of the years during which they have been already wrought. We need not be afraid then, of any sudden injury to Great Britain from the exhaustion of the coal mines. It is necessary to keep in mind, likewise, that I have taken the greatest thickness of the coal beds. Now as this thickness is far from uniform, a considerable deduction (I should conceive one-third of the whole) must be made in order to obtain the medium thickness; so that we may state in round numbers that this formamation, at the present rate of waste, will supply coal for 1000 years, but its price will be continually on the increase, on account of the continually increasing expense of mining.

Besides the coal exported to different parts of England, a large quantity is consumed in the two counties, which cannot easily be calculated. About thirty years ago a practice was adopted at the pits, where the coal was of a fragile nature, of erecting screens to separate the small from the sounder coal. This system is now become universal, and immense heaps of coal are thus raised at the mouths of the pits. These soon take fire from the heat of the decomposing pyrites, and continue to burn for several years.* Not less than 100,000 chaldrons are thus annually destroyed on the Tyne, and nearly an equal quantity on the Wear. Two such heaps in combustion may be seen at present (Nov. 1814) on the north side of Newcastle. If you travel from Berwick to Newcastle, and enter this last town in the dark, about three miles from the town, you see two immense fires; one on the left hand, about three miles from the road, which has been burning these eight years. The heap of coal is said to cover 12 acres. The other on the right hand is nearer the road, and therefore appears more bright; it has been burning these three or four years. These fires are not visible during the day, but only during the night. It has often occurred to me, says Dr. Thomson, that this small coal might be converted into coke with profit, and certainly in all cases where coal gas is wanted it would answer as well as any coal whatever.

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* Beneath the heaps that have taken fire, a bed of blackish brown scoria is formed, which greatly resembles basalt, and is used for mending the roads. (G. T. vol. iv. p. 54.)

§ 109. Wallis, in his history of Northumberland, gives an account of a fire happening in the *High main Coal bed* about 140 years ago, on the Town Moor and Fenham estates, which continued to burn for 30 years. It began at Benwell, about a quarter of a mile north of the Tyne, and at last extended itself northward into the grounds of Fenham, nearly a mile from where it first appeared. There were eruptions at Fenham in nearly twenty places; sulphur and sal ammoniac being sublimed from the apertures; but no stones of magnitude were ejected. Red ashes and burnt clay, the relics of this pseudo-volcano, are still to be seen on the western declivity of Benwell hill; and it is credibly reported that the soil in some part of the Fenham estate has been rendered unproductive by the action of the fire.

§ 110. The *choak-damp*, the *fire-damp*, and *after-damp* or *stythe*, are the miners terms for the gasses with which the coal mines are affected, and of these the second, both from its immediate violence and as occasioning the other kinds of damps, is the most to be dreaded. The accidents arising from it have become more common of late years; but it should not for a moment be supposed that they arise from any want of skill or attention in the professional surveyors of the mines. The following seem to be causes in which the gas originates.

1st. The coal appears to part with a portion of carburetted hydrogen, when newly exposed to the atmosphere; a fact rendered probable by the well known circumstance of the coal being more inflammable when fresh from the pit, than after long exposure to the air. 2nd. The pyritous shales that form the floors of the coal seams, decompose the water that lodges in them, and this process is constantly operating on a great scale in the extensive waste of old mines. In whatever mode we suppose the gas to be generated, it is disengaged abundantly from the High Main, but more particularly from the Low Main coal-seam, and in a quantity and with a rapidity that are truly surprising. It is well known that the gas frequently fires in a shaft, long before the coal-seam is reached by the sinkers; and that the pit-men occasionally open with their picks, crevices in the coal or shale, which emit 700 hogsheads of fire damp in a minute. These blowers (as they are termed) continue in a state of activity for many months together, and seem to derive their energy from communicating with immense reservoirs of air. All these causes unfortunately unite in the deep and valuable collieries situated between the great north road and the sea. Their air-courses are 30 or 40 miles in length, and here as might be expected the most tremendous explosions ensue.

The after-damp or stythe, which follows these blasts, is a mixture of the carbonic acid and azotic gases resulting from the combustion of the carburetted hydrogen in atmospheric air, and more lives are destroyed by this than by the violence of the fire-damp.

To guard against these accidents, every precaution is taken that prudence can devise, in conducting and in ventilating the mines. Before the pitmen descend, wastemen, whose business is to examine those places where danger is suspected to lurk, traverse with flint mills the most distant and neglected parts of the workings, in order to ascertain whether atmospheric air circulates through them. Large furnaces are kept burning at the up-cast shafts, in aid of which, at Wall's-end colliery, a powerful air-pump, worked by a steam engine, is employed to quicken the draft: this alone draws out of the mine 1000 hogsheads of air in a minute. A kind of trap door, invented by Mr. Buddle, has also been introduced into the workings of this colliery. This is suspended from the roof by hinges, wherever a door is found necessary to prevent the escape of air. It is propped up close to the roof in a horizontal position; but in case of an explosion, the blast removes the prop, whereby the door falls down and closes the aperture.

§ 111. *The minerals that accompany the coal strata are*, clay-ironstone forming thin beds or nodules in the strata of shale In the nodules of clay-ironstone are found galena and iron pyrites; and the latter is found in great abundance crystallized and disseminated in the beds both of coal and of shale. Calcareous spar is common, either blended with the coal, or in the form of stalagmites.

Sandstone.

§ 112. The beds of *sandstone in the Lead measures* are termed *hazles* when they are fine grained; when also they are ferruginous and hard, they are termed *sills*. When coarse-grained, they are called *grit*. This latter is quarried for mill-stones, and hence the bed is termed *mill-stone-grit*. Other beds have received names, either from their nature, or the purposes to which they are applied. Their whole number in the Lead measures amount to about 30. They are generally of a grey colour, with a tinge of yellow. The lower beds are the thickest; these are of 108, 156, and 180 feet respectively.

§ 113. *Sandstone* is termed *post* by the miners of the *Coal measures*; but when the bed is very hard it is termed *whin*; which therefore is not applied to basalt only, though most frequently. A bed 66 feet thick crops out at the hill called Gateshead Fell, on the south of Newcastle, and is quarried for grindstones which are of good quality. Great Britain and even the Continent are supplied chiefly from this place. The softer parts of the bed are used as filtering stones. There are about 25 beds of sandstone in the Coal measures; the greater number of them are thin.

In one of the sandstone strata, termed *fire-stone*, a tree has lately been discovered, 28 or 30 feet in length. The trunk and larger branches are siliceous, while the bark, the small branches, and the leaves, are converted into coal; and it is believed, that the small veins of coal, called by the miners *coal-pipes*, owe their origin universally to small branches of trees. It is stated by Mr. Winch, as a remarkable and interesting fact, that, while the trunks of trees in the Whitby alum-shale are mineralized by calcareous spar, clay-ironstone, and iron-pyrites, and their bark is converted into *jet*; those buried in the Newcastle sandstones are always mineralized by silex, and their bark is changed into common coal. (Ann. Dec. 1817, p. 68.)

Shale.

§ 114. The beds of *shale* or *slate-clay* amount to about 60 in the *Lead measures*, where the miners distinguish them by the name of *plate.* They are seldom so thick as 40 or 50 feet, but there is one of 70 feet. Some of these beds are soft, and crumble by exposure, or break spontaneously into thin slaty fragments, termed *shiver;* others are so hard as to require the blast by gunpowder; they are then termed *whin* by the miners; which term is also applied to a very hard sandstone, as well as to basalt; it seems to be given to any rock of considerable hardness.

§ 115. The beds of *shale in the Coal measures* amount to about 32 in number. Shale is called *metal* or *metal-stone* by the miners; thus they have *grey*, *blue*, or *black* metal, according to the colour of the shale; when very indurated it is called *whin* by the Newcastle colliers. The beds of shale are usually thinner than those of the sandstone with which they alternate. Both the sandstone and shale form the roof and floor of the coal-beds; but the latter much more frequently than the former. Each is to be seen in immediate contact with the coal, without the smallest sensible alteration in its properties. But a hard bituminous shale often forms the floor of the coal-beds, which is used by the manufacturers of fire-bricks.

Limestone.

§ 116. In the *Lead measures* there are about 20 beds of limestone, varying from 3 to 60 or 70 feet in thickness; in the aggregate they are 576 feet thick. These limestones are generally hard, of a blue colour, not of a crystalline texture, and are all without petrifactions except two of the beds; one of which is full of madrepores, and hard enough to take a polish;-the other is full of shells, and is called the cockle shell limestone. These limestones are considered as being characteristic of the *Lead measures.*

No beds of limestone occur in the *Coal measures.*

Lead Veins.

§ 117. We have still to give some attention to the very important subject of the lead veins, which have caused the name of *lead measures* to be given, though not with absolute propriety, to the large district of which they occupy only a small part. The mines are chiefly situated in the compass of about 15 miles from north to south, by about twenty from east to west; the southern boundary of this tract may be considered as a line extending about 20 miles eastward from Crossfell. In this tract of country, to which the lead mines are chiefly confined, there are no coal mines.

§ 118. In the district of the *lead mines* there are two descriptions of nearly *vertical veins.* Those which run north and south, or nearly so, are esteemed to be the oldest, but they are without lead; while those running east and west, contain it in immense quantity; they are the most numerous, and have been wrought for at least 200 years. Some are only a few inches wide, while others are several fathoms; but it is a curious circumstance, that these veins are found to vary in width in the different beds through which they pass. In passing down through the beds of shale, they frequently become narrow, but when traversing the limestone they widen considerably; so that a vein which was only two or three feet wide and very poor while in the shale, suddenly widened to the extent of 72 feet on entering the limestone, and became exceedingly rich in lead ore. The north and south veins are frequently filled by quartz; one of them, called the Devil's back bone, may be traced for a great distance, since it rises considerably above the surface of the strata down which it passes; it consists of nearly pure quartz, in which some copper ore and even galena have occasionally been seen.

The strata on one side of these *cross veins*, as they are termed by the miners, or north and south veins, are in some cases much higher than on the other side; in one instance as much as 100 fathoms: the same circumstance is observable on each side of the east and west or lead veins. Their *underlie* or *hade* is towards the north or south: when the underlie is towards the north, the strata are universally elevated on that side, and vice versa.

§ 119. Galena is the only lead ore procured in abundance from these mines. It contains silver, varying in the proportion of 2 to 42 ounces in the fother of 21 cwts.; 12 ounces may be considered as the general average, but 8 ounces are worth extracting. If the ore be of good quality, 32 cwts. of clean ore will yield 20 cwts. of lead.

Between 1803 and 1810, the greatest quantity of lead shipped in any one year at the port of Newcastle was 10,352 tons; the least 3,911. The average quantity shipped at Stockton, is about 3000 tons annually.

The whole of the lead mines of Great Britain are estimated to produce 45,000 to 48,000 tons per annum.

Basalt.

§ 120. *Basalt* is found both in the lead and coal measures. In the first, it occurs in the form of *beds* (see Plate 2, fig. 4,) interstratified with beds of sandtone, limestone, &c.; in *veins* which are termed *dykes;* and in masses lying on the surface, termed *overlying masses*. In the Coal measures it occurs, I believe, only in *dykes*. We will begin with the basalt of the former, as being the oldest part of the two formations.

§ 121. In the *Lead measures*, basalt forms a *bed*, varying from 36 to 180 feet in thickness, called the *great whin sill;* which, in one of the lead mines at Aldstone, is 159 fathoms from the surface. Other beds also exist. This basalt is of a coarse-grained texture, and is composed of white felspar, and black hornblende; and as the latter predominates, it gives to the rock a dark greenish grey colour. In composition, it does not resemble the basalt of the Coal measures. Basaltic *dykes* intersect the lead mine strata in Aldstone moor, Allendale, and in Weardale. One is quoted as being 36 or 37 feet wide. In the crevices beside the dykes, strings of lead ore are frequently observed, but are never known to pass through the dykes. In *overlying masses*, basalt occurs in the general form of a long range, crossing the country in the direction of north-east and south-west, on the north of the lead mines. Close to the edge of this range, the Romans constructed their wall, which is now standing four feet high in many places; this basalt is occasionally columnar. Higher north, other masses are also visible; and still higher, basaltic eminences form a striking feature in the country between Alnwick and Berwick. These eminences have frequently been chosen for the sites of castles, as at Dunstanborough, Bamborough, and Holy Island; some of the small islands near the coast are also composed of this rock. At Bamborough a well was sunk in the Castle hall to the depth of 150 feet, by which it was ascertained that the overlying rock of basalt is 75 feet thick, and rests upon a fine grained red and white sandstone.

From a cursory examination of some portions of the basalt of this district, Dr. Thomson refers it to the *newest flœtz trap* formation of Werner, (which supposes it to be of aqueous origin) and considers it, in some places, to consist of greenstone rocks, *seemingly deposited above the Independent Coal formation.* In reply to this supposition there is a paper in the Philosophical Magazine for August, 1817, by N. J. Winch, Esq. stating the following facts.

At Dunstanborough castle, and at Gunwarden castle, near Barwesford on the north, and at Wratchiff crag near Alnwick, basalt is *interstratified* with other rocks. At Dunstanborough, the cliff consists of

Columnar basalt. . 8 to 10 feet
Sandstone . . . . . . 2 feet
Shale or Slate clay 6 feet
Basalt to below the water's edge.

At Gunwarden, strata of dark bluish crystalline limestone, from three to four feet thick, alternate twice with compact basalt. At Wratchiff crag, basalt alternates with limestone and slate clay.

The Author then proceeds, 'It may not be amiss to notice a few phenomena usually accompanying basalt in this part of the kingdom, which may in some measure serve to develope its origin. *Limestone* is often *rendered highly crystalline and unfit for lime*, when in the vicinity of this rock, as is the case with the two lowermost strata at Wratchiff crag, but not with the upper one. *Slate-clay* or shale is turned into a substance like *flinty-slate or porcelain Jasper*, as is the case with the stratum lying immediately beneath the upper bed of basalt at Wratchiff crag; and *coal* is *invariably charred* when in contact with it. The *Sandstone* on which it sometimes reposes, is changed for some depth to a brick-red colour.

§ 122. The number of *veins*, or *dykes*, *traversing the strata of the Coal measures*, is very considerable, and there is no uniformity in their direction. The circumstances attending them, are in many cases very extraordinary, and the most considerable basaltic dyke in the immediate neighbourhood of Newcastle, is that which passes through Coley hill, about four miles west of the town.

A long range of quarries has here been opened upon it, in some places to the depth of 50 feet, and laying bare the entire width of the dyke, which is 24 feet. The dyke in this place appears to be *vertical.* The basalt of which it is composed, lies in detached masses which are coated with yellow ochre. The removal of these, brings to view thin layers of indurated clay with which the fissure is lined, and which, breaking into small quadrangular prisms, are used by the country people for whet-stones: in this substance, clay-ironstone impressed with the figures of ferns, is very abundant.

The upper seam of coal is here found at about 35 feet from the surface, and where in contact with the dyke, is completely charred, forming an ash-grey porous mass, which breaks into small columnar concretions, exactly resembling the coak obtained by baking coal in close iron cylinders in the process of distilling coal-tar. Calcareous spar and sulphur are disseminated through the pores of this substance.

The basalt itself, when broken, is of a greenish-black colour, and of a coarse-grained fracture. It contains quartz, calcareous spar, and another mineral possessing the following characters. The colour is wax-yellow passing into olive-green; the lustre vitreous, resembling that of glassy felspar; the fracture foliated. It resists the action of the blowpipe with borax, but with it melts into a white glass. The latter circumstance, and the foliated fracture, distinguish this substance from olivine, which gives a dark green bead with borax, and presents a fracture more or less conchoidal.

Passing to the east-south-east of the Coley hill dyke in the line of its direction, a vein is found traversing Walker colliery, and crossing the Tyne at Walker. This dyke is well defined; it occasions no alteration in the level of the coal strata, and the depth at which it intersects them is unknown. It has been cut through by horizontal drifts in four places. On each side of it, the *coal is converted into coak*, which on one side, in some places, was found to be 18 feet thick, and on the opposite side upwards of nine feet. A firm, hard, and unbroken vein of basalt, on an average about 13 feet thick, was in immediate contact with the coak on each side; and between these two veins, lay nodules of basalt and sandstone, upwards of nine feet in thickness, imbedded in a cement of blue slate.

At Walbottle Dean, five and a half miles west of Newcastle, below the bridge on the western road, a double vein of basalt (represented by Fig. 2, Pl. 4, of the 4th vol. of G. Trans.) crosses the ravine in a diagonal direction, passing nearly due east and west. It hades or underlies at an angle of 78 degrees, and cuts the coal strata without altering their dip. On the eastern bank of the ravine, it is laid bare from the level of the brook to the height of about 60 feet. The northern and southern basaltic portions of the vein, the one five and the other six feet in thickness, are there 13 feet apart, and are separated from one another by a confused heap of fragments of sandstone and shale, broken from the coal strata. With these fragments are found balls of basaltic tufa parting into concentric layers, and of a lightish brown colour; the balls are most abundant on the sides of the rubble near to the basalt. In a neighbouring colliery, both portions of the vein hold their course through the seam of coal, which is *charred* by their influence. This basalt contains nodules of quartz and chalcedony, but not adularia, which is abundant in the basalt of Coley hill.

A string of galena fills a crevice beside a vein of basalt about two miles beyond Durham.

A dyke called the Cockfield dyke, which is 17 feet wide, hades or underlies to the south, and throws up the Coal measures on that side 18 feet. The Low main coal contiguous to the basalt, is only nine inches thick, but enlarges to six feet at the distance of 150 feet from it. The *coal is reduced to a cinder*, and the sulphur is sublimed from the pyrites near to the dyke.

A dyke is seen on the banks of the Tees a little below Yarm. It there passes into the red sandstone, and continuing its course in the same direction, is well known to traverse the north-eastern part of Yorkshire.

§ 123. Besides the fissures filled with basalt, others of a very different nature intersect the coal strata. These, if large, are called *dykes;* but if inconsiderable, *troubles*, *slips*, or *hitches;* and are the same that some geologists have called *faults.*

The most celebrated of these is called the *Main* or *Great dyke*, or 90 *fathom dyke.* The latter name has been given to it, because the beds on the northern side are 90 fathoms lower than those on the southern side of it; its underlie is inconsiderable. In some places, its width is not great, but in Montagu colliery, it is 22 yards wide, and is *filled with hard and soft sandstone.* This dyke is visible in the cliff at Whitley quarry, a short distance north of the mouth of the Tyne, from which place it traverses the coal strata in the general direction of north-north-east and south-south-west, but not in a straight line; and it is considered to be probable that it passes into the Lead measures: a small string of galena has been observed in it at Whitby. From the southern side of this dyke, two others branch off, one to the south-east and the other to the south-west. The latter is very remarkable: it is called from its breadth, the 70 *yard dyke*, and is filled by a body of *hard and soft sandstone.* This intersects the upper or Beaumont seam of coal, which is not thrown out of its level by the interruption. The seam however decreases in thickness from the distance of 15 or 16 yards, and the *coal first becomes sooty*, and at length assumes the appearance of *coak. This phenomenon is unknown elsewhere, except in the vicinity of basaltic dykes.* The south-eastern branch is only 20 yards in breadth.

There are several other dykes of the same kind: these dykes, following the same law as the cross veins in the lead mine district, *elevate the strata on the side to which they dip.*

The dykes are an endless source of difficulty and expense to the coal-owner, throwing the seams out of their levels, and filling the mines with water and fire-damp. At the same time they are not without their use; when veins are filled, as is often the case, with stiff clay, numerous springs are dammed up, and brought to the surface; and by means of those dykes which throw down the strata, valuable beds of coal are preserved which would otherwise have cropped out, and been lost altogether. Several valuable beds of coal would not now have existed in the country to the north of the main dyke, but for the general depression of the beds occasioned by that chasm.*

§ 124. By far the greatest assemblage of basaltic rocks in this part of the district, is met with in Teesdale from the source of the Tees to Eglestone. At Caldron snout, situated on the moors ten miles above Middleton, a basaltic ridge crosses the river, and occasions a succession of cascades for the space of 596 yards, which form a fine contrast with the pool of still water or *wheel*, above the falls. It was here immediately under the basalt that the Rev. J. Harriman discovered small white garnets? crystallized in dodecahedrons, and imbedded in a thin stratum of pale red hornstone or chert with particles of calcareous spar.

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* In the 4th volume of the Geological Transactions, there is a short communication by the Hon. H. G. Bennet on a *Whin* dyke traversing the limestone and other strata in Beadnel bay on the north-east coast of Northumberland; by which it appears that the limestone is so altered in quality in those parts of it which lie in the immediate vicinity of the dyke, that it will not burn into lime of any value, nor within 20 feet of it. A stratum composed of felspar and carbonate of lime, is so altered near the dyke, as to resemble the substance of the dyke itself, which is unlike that of the dykes in the *north-western* part of the county; these are composed principally of hornblende.

Near the steep acclivity which terminates Cronkley Fell, another range of basalt interrupts the course of the Tees, and causes the cataract called the High or Mickel force, where the water is precipitated from the height of 56 feet. The rock which here crosses the river, is apparently an *overlying mass* of coarse-grained grey basalt, the hornblende and the felspar which compose it not being intimately blended. It rests upon the lead-mine sills, and shoots, on the banks of the Tees, into regular columns of considerable magnitude and elevation. A few miles below this cascade, and about three above Middleton, perpendicular basaltic rocks again form the banks of the river. To these, iron chains have been fastened for supporting Winch bridge.

This remarkable structure, if it can be so called, is a plank two feet in breadth, with low hand rails, suspended 56 feet above the Tees, which is here 63 feet wide. Some miners contrived it for the purpose of passing from the county of Durham to Holwick in Yorkshire.

In the fragments of basalt which are found scattered over the surface in Teesdale, and in other parts of the district, small grains of yellow olivine, and of greenish black augite, are found imbedded. (G. T. vol. iv. p. 73.)

§ 125. We have no very intelligible account of the great *Derbyshire Coal-field*, which is considered to be united with that of Yorkshire. The coal strata of Derbyshire are traversed and dislocated by an immense *fault* proceeding from near the termination of the magnesian limestone range on the south, northwards, in a zig-zag direction, on the western side of that limestone, quite into Yorkshire. Of this fault, nothing has I believe been said in regard to its size or contents: but it is believed to be owing to it that the coal strata of Derbyshire and Yorkshire, through which it passes, are on the west of it, so dislocated, that it would be extremely difficult so to connect the beds of coal, and the interposed substances, as to form a reasonable conclusion as to their number and nature. The beds of coal west of the fault, are known to pass beneath the magnesian limestone, since they are worked beneath it, (§ 90).

It is ascertained that the strata of which the whole formation consists, are numerous. There are 20 gritstone beds, numerous strata of shale, bind, and clunch, alternating with several beds of coal of different thickness and value. The whole series lies upon a gritstone (termed the millstone grit, § 137), beneath which no workable coal is found; and the gritstone reposes upon the series of beds of mountain limestone and toadstone (§ 132) which basset or crop out at the surface on the western side of the county, forming its great mountain ridge. Some of the *gritstone* beds are of great thickness, and are described as consisting of grains of semitransparent silex, which do not appear to be rounded by attrition, united by an argillaceous cement; in some of the beds, there are smaller ones, in which the cement is very small in quantity, and from which are quarried grindstones for cutlers, &c. The beds of *shale*, consist of a slaty argillaceous substance of a black or brown colour, rarely of a light yellow; their joints are ochreous;

and the springs of water issuing from them are tinged by iron. Some of them contain a sort of muscle shell, and anomia shells, but not commonly; and roundish or ovate masses of *argillaceous iron-stone*, and even thin strata of it, in which are coaly impressions of vegetables. These iron-stones dip, of course, with the strata, beneath the grass; and the workings of them, which are numerous, are begun at the surface, and pursued until it becomes dangerous, from the loose nature of the stratum in which they lie, to follow them deeper. In some places, where the texture of the bed is favorable, the iron ore has been followed down 35 or 40 yards. This ore also is found in the beds which are by the miners called *Binds*, which appear to be beds of indurated loam, or of sand and clay mixed and indurated, and which are inclosed in the shale just noticed; the bind falls to pieces on exposure, however hard it may be in its natural state and position. When the sand abounds, and the bed is very hard, it is called stone-bind, and it then contains scales of mica. Binds are black, or blue, yellow, grey, &c. Some of the very hard black binds are used as black chalk by the stone mason. Others when decomposed become good brick clay, as well as the *Clunches*, which we have yet to notice. Clunch is indurated clay, and yields those infusible kinds which are adapted for fire-bricks; it varies in hardness, and is black, grey, yellow, white, &c. Clunch is generally found immediately beneath each bed of coal, and at the places where it bassets or crops out on the surface, becomes soft clay. (F. passim.)

But besides the fault just now noticed as traversing the coal in the direction of north and south, on the western side of the magnesian limestone, and others which are found in the Coal-field, and which have hitherto prevented an accurate description of its strata, there is a very extensive one which runs in the direction of nearly east and west; proceeding from near Nottingham, so as to pass the southern termination of the magnesian limestone range, and for some distance on the west side of it. The consequence of this fault is described as being very important; inasmuch as the Derbyshire coal-field, which is on the north of it, has been, as it were, *raised to a level with the red marle* on the south of it. (F. 165.) That is to say, the coal, which is commonly beneath the red marle, as near Bristol and other places, is here on a level with it. Hence it seems reasonable to conclude that the fault was once a fissure, caused by the elevation of the strata on the one side, or by their depression on the other; this may appear theoretical at first, but when we recollect that not only in coal countries, but in those producing copper and tin, as in Cornwall, the regular veins have been altered in their position on one or the other side of the cross veins, in at least a thousand instances, we shall scarcely esteem it to be theoretical; and we shall judge them to have been fissures, consequent to the partial elevation or depression of the strata, from causes which now are inexplicable.

§ 126. Of the *Shropshire coal-field* there is an account in the first volume of the Transactions of the Geological Society, to which I must refer the reader, since it is impossible here to do justice to that communication. In general terms, however, it may not be amiss to say that a sandstone prevails in its neighbourhood, which is judged by its characters to be the *old red sandstone* of Werner. The Staffordshire coal beds dip rapidly towards this sandstone in a westerly direction, and those of Shropshire in an easterly direction; the sandstone between the two formations being 12 miles wide. It has not been ascertained that they pass beneath it. The independent coal formation of Shropshire is found immediately adjacent to the sandstone, from Wombridge in the parallel of Wellington to Coal-port on the Severn, a length of about six miles; its greatest breath is about two miles. It is composed of the usual members, namely, of *quartzose sandstone*, of *indurated clay*, of *clay porphyry*, of *slate clay*, and of *coal*, alternating with each other without much regularity, except that *each bed of coal is always immediately covered by indurated or slaty-clay*, and not by sandstone. *Trap*, or *greenstone*, appear in some places between the coal formation and the limestone on which it rests. The series immediately belonging to the coal formation is most complete in the deep of Madely colliery, where a pit has been sunk to the depth of 729 feet through all the beds, *eighty-six in number*, that constitute this formation.

The *sandstones*, which make part of the first 30 strata, are fine-grained, considerably micaceous, and often contain thin plates or minute fragments of coal. The 31st and 33d strata are coarse-grained sandstone entirely penetrated by petroleum; they are, both together, fifteen feet and a half thick, and furnish the supply of petroleum that issues from the *tar-spring* at Coal-port. At the depth of 430 feet occurs the first bed of very coarse sandstone or grit; its thickness is about 15 feet. The next bed of sandstone deserving notice, occurs at the depth of 576 feet, is about 18 feet thick, is fine-grained and very hard, and is often mixed with a little petroleum; the name given to it by the colliers is the *big* *flint*. The lowest sandstone, called the *little flint*, is the 85th in number, and is about 15 feet thick; the lower part is very coarse and full of pebbles of quartz; the upper is of a fine grain, and sometimes is rendered very dense and hard by an intimate mixture of iron ore; it occurs at the depth of 705 feet. Vegetable impressions are met with in most of the sandstone beds, but it is not known that they contain shells.

The *clay-porphyry* occurs only once in the whole series; it forms a bed nine inches thick, at the depth of 73 feet from the surface. It consists of a highly indurated clay of a liver-brown colour, in which are imbedded grains of quartz, of hornblend, and of felspar.

The *indurated clay* is in some beds compact, dull, and smooth; it is then termed *clod:* in others it is glossy, unctuous, and tending to a slaty texture, and is then called *clunch*. It encloses beds of *clay-ironstone* in the form of compressed balls, some vegetable impressions, and a few shells. The beds of iron ore are five or six in number; they all lie in the indurated clays, and all consist of balls or broad flat masses.

The *Slaty clay*, called by the miners *basses*, is of a bluish black colour and slaty texture; it usually contains pyrites, and is always either mixed with coal, or combined with petroleum; in the former case it passes insensibly into slaty coal, and in the latter into cannel coal.

The first bed of *Coal* occurs at the depth of 102 feet from the surface, is not more than four inches thick, and is very sulphureous; nine other beds of a similar nature, but somewhat thicker, lie between this and the depth of 396 feet. They are termed stinking coal, and are employed only in the burning of lime. The first bed of coal that is worked is five feet thick, and occurs in this colliery at the depth of 496 feet; between this bed and the big-flint sandstone, are two beds of coal, one ten inches the other three feet thick. Between the big and little flints, which are about 100 feet apart, lie nine beds of coal of the aggregate thickness of about 16 feet. Beneath this, and the lowest bed of the whole formation, is a sulphureous eight-inch coal. The best coal of the above beds, usually presents a mixture of slate coal and pitch coal, rarely of cannel coal; none of it possesses the quality of caking.

Of the numerous beds visible in this colliery, some are wanting in the neighbouring ones, and there exists also a considerable difference in the thicknesses of the respective beds.

The whole *Coal formation rests either upon die-earth, or limestone*, except that at one place *greenstone-trap* is interposed between the coal and limestone.

The *Die-earth* is so named from the fact that the beds of coal die or cease beneath it. Its colour is greyish; it consists of fine sand, of particles of limestone, and of clay, mixed together in various proportions; it is often also micaceous. It contains a few bivalves, chiefly of the genus cardium, and the entomolithus paradoxus, or Dudley fossil. The thickness of this bed varies from a few feet to an hundred yards; it encloses fragments of limestone, and is interposed between the limestone and the Coal formation, without possessing the dip or direction of either the one or the other.

The *Greenstone-trap* is described as being perfectly unstratified, and as forming two principal deposites; the one constituting the chief mass of the hill on which the town of Little Wenlock is built, the other that of Steeraway hill. At the former place, this rock appears for the most part to occupy the space *between the Coal formation and the subjacent limestone*; and accordingly, at the eastern foot of the hill may be seen the great body of the coal at its usual angle, while the little flint sandstone *(the lowest member of the Coal formation)* highly elevated, covers the ascent of the hill, and is found in several detached patches on its summit, but in nearly horizontal strata. Of the greenstone there are several varieties. Occasionally it appears to be composed of hornblende and felspar, with a little calcareous spar and mica. In some places it consists chiefly of greenish-white felspar and hornblende in small masses, coated by calcareous spar; but sometimes it is more or less *amygdaloidal*, inclosing globules of radiated calcareous spar. In others, it includes a predominating proportion of flesh-coloured felspar, giving to the rock a sienitic appearance. (G. T. vol. i. p. 203.)

The *Limestone* formation in the neighbourhood, appears generally speaking to have the same characters as the mountain limestone, which commonly is found connected with the Coal formations of England. It consists of beds of limestone and sandstone, forming two mountain ranges in the direction of N. E. and S. W. The limestone contains madrepores, particularly the catenaria or chain coral, pentacrinites, small ammonites, and a few bivalve shells. At the northern extremity of one range where it comes in contact with the Coal formation, the limestone contains cavities which are lined with, or are full of petroleum. The intersection of the limestone hills by vallies, and the variations in the dip of the strata composing them, have given rise to the supposition of their having been subjected wholly or in part to subsidence or elevation. (G. T. vol. i. p. 201).

Beneath the limestone is a *Trap formation;* but between them, lies a *slate-clay* containing substances having the impression of marine remains; also a *quartz-grit*, and a bed of *claystone* or *compact felspar*, which reposes on the trap formation. (§ 178.)

§ 127. In the Geological Transactions, (vol. iii.) there is a very interesting account of a "*Bed of Trap* occurring in the colliery of Birch-hill, near Walsall *in Staffordshire*, by Arthur Aikin, Esq." This bed forms one of the strata of the Coal-deposite. It lies upon an indurated sandstone, and is covered by a bed of slaty clay: it varies in thickness from 12 to 27 feet, thinning off as it recedes from a mass of the same substance, forming a hillock above the surface on the verge of the mine, and with which it is supposed to be connected. The bed of the *Green rock* (as it is termed by the miner) is separated from a bed of coal, by a bed of indurated sandstone a yard thick, and seems to have had no further effect on the coal, than that of depriving it of its bitumen, thereby reducing it to the state of *blind coal.* The coal and the numerous intervening strata, are intersected and dislocated by *fault*, as it is expressly termed in the mining country, which consists of the same material as the Green rock itself, whence it is concluded that they are connected.

The Green rock is considered to be one of the varieties of Trap rocks, called *greenstone*, being composed primarily of felspar and amorphous hornblende. It contains also carbonate of lime.

Professor Jameson, in his mineralogical account of Dumfrieshire, mentions beds of greenstone as occurring in the independent Coal formation.

§ 128. The *Great Coal-field of South Wales*, extending from Pontipool on the east to St. Bride's Bay, south of St. David's head, on the west, belongs to the independent Coal-formation; and is situated in a large limestone basin. The limestone crops out at the surface all round the coal, except where its continuity is interrupted by Swansea and Caermarthen bays. The deepest part of this basin is in the neighbourhood of Neath, which is near its centre: and below Neath, or a little to the west of it, the lowest strata of coal are nearly 700 fathoms lower than the outcrop of some of the superior strata in the more hilly parts of this district. The bed of coal which is nearest to the surface, lies (near Neath) about 60 fathoms beneath it, and rises to it about a mile north and south, and also a few miles east and west of the deepest part of the basin. So that we are to imagine the inferior beds of coal rising to the surface all round the outcrop of the superior stratum, and between it and the basset edges of the limestone basin. If a line be drawn from Pontipool on the east to St. Bride's bay on the west, it may be said that all the beds of coal on the north of that line crop out on the north of it, at distances proportionate to their depth beneath the surface: so also those on the south of that line, rise to the surface on the south of it; except near Pontipool, where they rise towards the east.

It appears however that, though the lowest bed of coal is so far beneath the greatest elevations of this district as near 700 fathoms, the miner finds it without any very considerable descent: for the whole country is intersected by deep vallies in a north and south direction, which consequently cut the strata of the coal. The miner therefore, taking advantage of this circumstance, drives levels into the hills, and there finds the beds of coal and ironstone; there are however many mines in vallies and low places.

There are 12 beds of coal from three to nine feet thick, making together 70½ feet; and 11 others from 18 inches to three feet, making 24½ feet; together 95 feet of workable coal, besides numerous other beds from six to 18 inches thick. By taking the average length and breadth of the Coal-field, the amount is about 1000 square miles, containing 95 feet of coal in 23 distinct strata, which will produce in the common way of working, 100,000 tons per *acre*, or 64,000,000 tons per square mile.

The coal on the north-eastern side of the basin is of a coaking quality, on the north-western it is what is termed stone-coal (the large of which is used for drying malt and hops, and the small, which is called *culm*, for the burning of limestone); on the south side, from Pontipool to Caermarthen bay, the coal is principally of a bituminous or binding quality.

Near the western termination of the basin, beyond Caermarthen bay, it is shallower, so that the beds of coal, found in the deeper parts, are not found there.

Of the *iron-ore* contained in this basin we have but little that is satisfactory; nothing on the methods of working it. It appears that the lower beds of the deposite enclose parallel strata of iron-ore, of which there are in some situations about 16, accompanied by irregular balls or lumps of iron ore. The latter are also found in regular strata at various depths, between the beds of coal. (P. T. 1806, p. 342.)

In the communication from which these extracts are made, no account is given of the nature of the beds reposing upon or between the beds of coal, or on the subject of the organic remains they contain.

This Coal-field is traversed by *dykes*, or *faults*, generally in a north and south direction, which throw all the strata from 50 to 100 fathoms up or down; but they do not appear on the surface; no account is given of their nature or extent.

§ 129. The deposite of *Coaly matter* found near *Bovey Tracey* in Devonshire, and thence termed Bovey coal, is not a member of the Independent Coal formation, but of the newer, termed Wood-coal. The principal beds are found beneath the surface of a common called Bovey Heathfield, 13 miles south-west of Exeter, and three miles west of Chudleigh. The surface consists of a white sand intermixed with an ash-coloured clay.

The thickness of the whole deposite, including the beds of clay with which the strata of coal are interstratified, is about 70 feet. There are about six beds of coal and as many of a brownish clay. The upper stratum of coal varies from 18 inches to four feet in thickness, and each succeeding stratum is thicker, so that the lowermost is 16 feet thick. The latter lies on a bed of greenish sand about 17 feet thick, reposing on a bed of hard close clay, which has been bored into, without finding coal. These strata are known to extend a mile in one direction. They dip 20 inches in a fathom towards the south.

The clay near the coal is somewhat bituminous, and small grains of coal resembling reeds and grass, are found in the beds of clay; in which, but adhering to the veins of coal, occur lumps of a bright yellow loam, extremely light, and so saturated with petroleum (Retinasphalt) that they burn like sealing-wax, emitting a very agreeable aromatic scent.

The substance and quality of each stratum of coal is pretty much alike; but some differences are found to exist. In the centre of the lowermost stratum especially, there are beds which are more compact and solid, black, and almost as heavy as common coal; these do not so readily divide into laminæ, are more bituminous, and make a more lasting fire. These are distinguished by the name of stone-coal. But the most remarkable of all the strata is that which is termed wood-coal, or board-coal, from the resemblance of its grain to that of deal boards. It is sometimes of a chocolate colour, sometimes black, still more bituminous, but not so solid as the stone coal, and lies in straight laminæ, and is frequently taken out in pieces of three or four feet in length. When first dug, it is moist, and readily bends, but by exposure becomes dry and crisp. Small protuberances sometimes appear resembling knots of trees.

But though the texture of this coal is laminated, it does not appear to have the woody substance; and it is said that no appearances of branches or stems of trees have been discovered. (P. T. 1760, p. 534.)

MOUNTAIN LIMESTONE.

§ 130. This rock, which is common to Derbyshire and many other parts of England, has obtained the name of Mountain Limestone, to distinguish it from some other limestones, which, though most of them agree with it in the character of forming considerable elevations, differ from it in point of composition and geological situation. It is a secondary rock, abounding with marine shells, and enclosing coralloids, madrepores, &c. and is intersected by numerous metallic veins, chiefly of lead, more rarely of copper. It sometimes contains beds of swinestone, as in Derbyshire, Shropshire, and Northumberland; and is associated with more compact varieties, which, as they admit of a high polish, and are sometimes beautifully variegated, have obtained the name of marble.

It is, I believe, an undisputed fact that all the independent coal formations of England and Wales, rest upon beds or strata of limestone, greatly resembling the limestone of Derbyshire in respect of the organic remains it contains. (§ 95 & seq.)

§ 131. The mountain limestone formation of England consists of many beds of rocks which differ greatly; even the beds of limestone do not always resemble each other, either in aspect or chemical composition; and the substances with which they are interstratified, consist of marles, clays, sandstones, and even coal. Amygdaloid also is found between the strata of limestone in

Derbyshire, and basalt in the north of England; but the nature of these rocks is yet far from being accurately understood (§ 179): one circumstance is remarkable; namely, that although they lie between beds of limestone full of organic remains, they contain none. This has in part been the cause of much theoretical reasoning on their nature, and the relative time of their formation, with which here we have nothing to do. Our objects are geological facts. In the following notice of the mountain limestone formation of England, a short account will be given of the substances with which the limestone is interstratified; and amongst them of basalt and amygdaloid; referring the reader to the "order of superposition," &c. to be found at the close of this volume, for an account of the class which has been theoretically assigned to these rocks, and which is altogether Wernerian: the great similarity in their position, however, evinces that there is much analogy between them (§ 121, 134). But it will appear from the extraordinary circumstance attending the whin or basalt, occurring in veins or dykes in the great coal-field of the north of England (§ 122), that there is some reason for doubting whether it be of the same origin as the basalt and toadstone occurring in beds.

§ 132. The mountain limestone tract of *Derbyshire* extends from Castleton, which is its northernmost point, about 25 miles south of that place; its breadth does not appear any where to exceed about 15 miles. Its form on the surface is very irregular. The Peak forest extends over its north-western extremity; on the south of which, Buxton is situated on the western edge of this tract, Matlock is on its eastern extremity. The surface of this district is occupied by the *out-crop of four strata of limestone, and of three beds of toadstone which lie between the strata of limestone.* Upon the upper bed of limestone rests a stratum of shale, containing beds of limestone; and on the shale reposes a stratum of grit-stone; the out-crop of these two beds being on the east of Matlock. All these beds have a general direction on the surface from north to south, and dip, in some places at least, towards the east, passing beneath the coal measures (§ 125), which, on the surface, and under it, lie between the mountain limestone, and the magnesian limestone (§ 86) on its east. In this part are situated the numerous lead mines of Derbyshire, and even some mines of copper.

§ 133. We have to notice the nature of the strata of *limestone*, *toadstone*, *shale*, and *gritstone;* and shall afterwards say a few words on the veins passing through them.

The *lowest stratum of limestone*, being that, on the out-going or outcrop of which are situated the Peak forest, Buxton and many towns on the south of it, passes across Dove dale and Wetton dale: the Weaver hills consist of it. In it are many caverns, as the immense one called Elden hole, north of Peak Forest town; the Devil's hall, connected by a tunnel with the Speedwell mine; Pool's hole near Buxton, and several of less note. Its stratification, and that of all the superior strata, is in many places greatly affected by what is termed a great limestone fault (F. 280 & seq.), but of which I have not been able to discover any account, except of its direction; it is very long and circuitous. The thickness of this lower limestone stratum is not known; we are consequently ignorant of the rock on which it rests. It is regularly stratified, consisting of very many beds, several of which are of considerable thickness; some thin ones are described as being a *freestone* (sandstone?): its colour varies from white to a yellowish stone colour, it rarely includes dark coloured beds. Small entrochi, numerous anomia and other shells and organic remains, occur throughout the whole of this stratum: in some mines, a thin bed of clay had been found in it. The lime yielded by this stratum is preferred to that of the strata above it. A bed of toadstone lies on it, but I propose to notice together the three beds of this substance, and therefore proceed to the

Second stratum of limestone. This is about 210 feet in thickness, and consists also of many beds; the superior ones are often of a dark colour, and contain nodules of black chert, shells of the genus anomia, madrepores, &c.; some of the beds are quite black. It contains layers of clay, and towards the lower part of it, some dark beds of limestone contain white madrepores. Imbedded masses of toadstone occur in it. On this lies another bed of toadstone, to which succeeds a

Third stratum of limestone. This, like the two preceding strata, consists of many beds whose average thickness is about 150 feet: and it is worthy of note that several of them are of magnesian limestone. In some places the upper beds partake so greatly of the nature of chert, as to be unfit for the purposes of the lime-burner; these cherty masses are usually called in Derbyshire, *dunstone*, or bastard limestone. Here and there are masses of white chert or china-stone. Some few beds contain entrochi; and towards the lower part are beds of a very black limestone, which, as it takes a very brilliant polish, is termed black marble. It contains thin beds of clay On this stratum lies the third bed of toadstone, on which reposes the

Upper Limestone. This, like the preceding, is about 150 feet in thickness. In it, as in the three lower strata, some thin beds of clay are found, and it contains imbedded masses of toadstone, though rarely. The upper beds are of that variety of limestone called swinestone, and are often dark coloured or black: near the top are found layers of nodules of black chert, similar in their arrangement to the flint nodules in chalk; in the upper beds also the shells called anomia, and others, are common. The middle beds contain vast assemblages of entrochi, and are occasionally quarried as marbles; and it is remarkable that in some places, where these middle beds basset out on the surface, masses are ploughed up from beneath the alluvial soil, exhibiting the casts of the inside of entrochi in chert; these are commonly called *screw-stones.* Blocks of these were heretofore used in the forming of mill-stones, which were employed instead of the French buhr-stone. This stratum contains beds of what is termed white chert or china-stone, of which considerable quantities are used in the Staffordshire potteries.* (F. 271 & seq.)

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* It is in a mountain composed of limestone, that the beautiful masses of various coloured fluor spar, termed Blue John, are found. The mountain has no appearance of regular stratification, and is full of fissures and caverns of immense depth: the fluor occurs in those nearly horizontal beds, or rather openings, which are termed *pipe veins* (§ 138), and is found of a roundish form, in which it seems to have crystallized; but the centre is frequently hollow. It is from these masses that elegant vases, &c. are manufactured by Mawe & Co. (M. 69.)

§ 134. We come now to the consideration of the *three beds of Toadstone interstratified with the four beds of limestone.* These are said to be true and regular, and are so calculated upon by intelligent miners; yet in several places they have proved of great thickness, and in others very thin; in no place are they entirely wanting; the average thickness of the two undermost beds is about 75 feet, the upper bed is about 60 feet thick. But it is requisite to say, that each of the limestone strata encloses masses of toadstone, which are not connected with the regular strata of that substance; to which is attributed the suspicion entertained by some that it is not stratified at all. (F. 279.)

All the strata of limestone and toadstone are said to basset out in certain places in the district before mentioned, but their perfect regularity and continuity in this respect, appears to have been greatly affected by the fault already mentioned.

The toadstone is described as a compact, hard, ferruginous stone, somewhat of the colour of the back of a toad, whence its familiar name. It frequently effervesces strongly with acids, and contains globules of whitish calcareous spar from the size of a pin's head to that of hazle nuts, or larger, having the appearance of rounded pebbles; these nodules, when exposed at the surface, fall out, leaving the imbedding substance with a cavernous or porous aspect. Occasionally it is schistose; in other places it appears as a clay, both in deep mines and on the surface, and is of a bluish grey colour. In these clays, it is said that masses of basalt, and others of the hardest class of these stones, occur, and occasionally in the same shapes as the pentagonal basaltic columns. It is not uncommon to find in the upper bed of toadstone, chalcedony, hornblende, jasper, zeolite, and green earth. (F. 413.)

In the *cave* at Castleton, which is a deep ravine at the back of the castle, the toadstone is seen in the form of an irregular column, is as hard as ordinary basalt, compact, and contains hornblende and some patches or streaks of red jasper: a similar variety is also found near Buxton, containing zeolite and chalcedony. The toadstone has no internal appearance of stratification; no impression of vegetables, nor of marine exuviæ, which occur plentifully in the limestone in which it is interstratified.* (M. 40.)

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* The great *whin sill* of the lead miners in the north of England, is described as being a bed of *basalt*, coarse-grained in texture, and composed of white felspar and black hornblende, the latter predominating and giving to the rock a dark greenish grey colour. It lies between beds of limestone, &c. (§ 121), and therefore in point of situation agrees remarkably well with the *toadstone* of Derbyshire. (G. T. vol. iv. p. 73.) I am not aware that the latter rock has ever received the name of basalt, though it occasionally assumes its character and hardness. The actual distinction between the toadstone of Derbyshire and the basalt of the north of England, has never been clearly pointed out; and since their geological position is the same, is there not reason for concluding that they are of the same origin, and therefore that they ought to receive the same designation? By the preceding account of the toadstone, it will be observed that its characters differ essentially in different places, which also is the case with some of the basalts of the northern parts of England, especially of those found in what are termed *overlying* masses (§ 121). Both are considered as *trap rocks.* If the reader be desirous of inquiring into the probable origin of basalt, and of other rocks usually associated under the general name of *flœtz trap*, he is particularly referred to a very candid and ingenious note on that subject by the Rev. W. Conybeare, inserted in the 3d volume of the Transactions of the Geological Society, p. 208.

§ 135. Near Hopton hall, where the lower bed of toadstone rises to the surface, a *vertical* vein six inches wide, was found in it, in 1796, in making a road. In the part which was first seen, it was filled with a bright coaly or bituminous substance, which was highly inflammable; this soon terminated abruptly against one of those substances, which occasionally receive the name of trap, or amygdaloid, which is a variety of trap, or basalt; and the vein is then described as having the appearance of a *whin-dyke*, and as being the only instance of the kind in the county. (F. 175.) For some account of the basaltic or whin dykes of the great coal formation surrounding Newcastle, see § 122.

§ 136. The *Great shale*, or *Limestone shale*, *resting on the uppermost of the four beds of limestone*, occupies a large tract on the surface. Its thickness is averaged at about 450 feet. Its general colour is black; it disintegrates on the surface, forming a strong loam or clay; which, when it is not too wet, is a very productive soil; but in some places the shale itself is durable, remaining for ages in the soil, of the size of a half crown or a penny piece, from which it is presumed to have taken the name of *penny shale*. From the decomposed shale of this stratum, bricks and tiles are made in several places. It contains occasional beds of a fine-grained siliceous freestone, full of mica in minute plates, and is stained with concentric rings of several shades of yellow and red. It is considered to be the most perfect freestone of the district, and is quarried in several places, having been used in the construction of some of the finest buildings in Derbyshire. This stratum also contains great masses, and occasional beds of a dark blue or black limestone, which at Ashford is quarried as a black marble. The stratification of this shale is by no means regular, being in different places horizontal, inclined, and even contorted. The *rottenstone* of Derbyshire is considered to arise from the occasional decomposition of these limestone beds, near or upon the surface. They sometimes contain *ironstone.* This stratum encloses *vegetable impressions;* and some beds of *coal* of small extent, varying from a quarter of an inch to two inches in thickness. *Sulphur*, in small quantity is found in its cavities, and *geodes of limestone* filled with liquid *bitumen* in several of the mines. (F. 227 & seq.) The hot springs of Buxton issue from this stratum. (M. 24.)

§ 137. We have now arrived at the consideration of the stratum of *Gritstone overlying the stratum of shale, the four limestones and three interposed beds of toadstone.* It is requisite here to remark that this gritstone is the stratum on which the great Derbyshire and Yorkshire coal measures lie; so that its situation might render it in some degree uncertain, whether it ought not to be considered as a member of that important series, rather than as belonging to the limestone formation: but the question seems decided in favour of the latter, by its containing metallic veins in common with the limestone. It is interposed between the shale and the coal, and the places at which it crops out on the surface from beneath the latter, are known with great precision along a great length of country. This stratum has been proved to be 360 feet thick in several places; and is composed for the greater part of a very coarse-grained white, yellowish, or reddish freestone, which is easily worked considering the extreme hardness of its particles, and is of great durability. It has long furnished millstones of pretty good quality, of which formerly there were several quarries, but they are now chiefly quarried at Old Booth-edge in a very inaccessible part of the county: hence this stratum has been termed the *millstone grit.* It affords also fire-stone for the hearths of iron-furnaces, since it endures heat remarkably well. The upper beds are very thin; these are used for paving stones, and sometimes are so thin as to be employed for the roofing of houses. (F. 220 & seq.)

§ 138. The out-going of the strata just described, forms the great *Lead district* of Derbyshire; very numerous veins have been worked in it principally for lead, but the ores of zinc, manganese, copper, and iron, also occur in them; but they are more plentiful and productive when in the limestone, than when in the other strata. It has been supposed that lead ore has not been found in the toadstone, but nineteen instances of its discovery in that situation, in strings and short branches, are mentioned. (F. 250.) A vein, somewhat approaching the *perpendicular*, is in Derbyshire termed a *rake vein.* Rake veins are from 2 or 3 to 30 or 40 feet wide. A large cavity, often nearly *horizontal*, between beds of limestone, and containing spars and ore, is termed a *pipe vein.* Veins (or rather beds) of this description are sometimes of considerable height, and from 2 to 500 feet wide, and are commonly connected with the surface by means of a rake vein; when without this kind of connexion, the nearly horizontal deposite is termed a *flat-work*, which is rare. The direction of the veins containing ore, appears to be nearly east and west, and their hade or underlie beneath the surface, towards the north or south; but in this respect, it is said that a vein will change two or three times from north to south: these veins are crossed by others whose direction on the surface is nearly north and south. The east and west veins in descending are always *cut off by the strata of toadstone*, which therefore pass through and divide them; and it is worthy of note, that when the vein is again found in the stratum of limestone beneath the toadstone, it is not *immediately on a line* with the upper part, nor exactly of the same nature; in this case a vein is said to have *squinted*. The toadstone is said sometimes to assume the consistence of clay. It has been before noticed that the limestone strata contain thin beds of clay, termed by the miner *way-boards*; these sometimes pass through and divide the veins of ore in the same manner as the toadstone does: and so complete is the separation of the veins of ore by the clay and the toadstone, that not even the water in the upper part of the vein penetrates through them into the part beneath. The sides or walls of a rake vein are commonly lined by fluor, or cawk, or calcareous spar, termed by the miner *vein-stuff;* between, or against these, lies the ore, which sometimes fills up the space between them, and is then termed a *rib of ore*. But it sometimes happens that the vein-stuff of each wall of the vein, is nearly compact, both so completely occupying the vein, that they meet together in close contact in the middle; forming what may be termed from its appearance, a vertical crack down the vein. The two faces in contact, appear as though they had been polished, and are ribbed or somewhat fluted horizontally; and the face of each is sometimes covered by a remarkably thin coating of lead ore; these planes, when separated, are the *slickensides* of the mineralogist.

This circumstance is altogether remarkable in itself, but an extraordinary effect ensues when one side of the vein-stuff is removed. The other side then cracks, especially if small holes be made in it, and fragments fly off with loud explosions, and continue so to do for some days; as is the case in the Gang mine in Cromford, where the miner, availing himself of this circumstance, makes with his pick small holes about six inches apart and four inches deep, in one surface, after the other is removed; and the consequence is, that on his return in a few hours, he finds every part so treated, ready broken to his hand. (M. passim. F. 243, and seq.)

§ 139. Of those remarkable derangements in the strata of Derbyshire, termed *faults* by the miner, we have no very clear geological account. The direction of some of them on the surface is detailed in the 1st volume of Farey's General View of Derbyshire, &c. to which I refer the reader: occasionally they appear to be very extensive, and their consequences very extraordinary; but a knowledge of their width, dip, and contents is yet a geological desideratum. Some of them have intersected the veins of lead ore, and are said to have introduced rounded quartz pebbles or gravel, alluvial clay, and other extraneous mineral matters, into them.

§ 140. We shall now assume some consideration of the Mountain limestone formation near *Bristol.* The hills which rise from beneath the red marle or new red sandstone on the west of Bristol, form a range of considerable elevation, through which the Avon passes in its course to the Severn. This range consists of a prodigious number of strata or beds of very different natures, the dip of which is about 45 degrees. The beds are chiefly limestones of several varieties; arenaceous, schistose, spathose, granular, compact, and even of an oolitic texture. Some of them contain broken shells, encrinites, anomiæ, and other organic remains. An assemblage of numerous strata, called the Black rock, from the colour of the limestone, contains many fossils, as entrochi, anomiæ, the palates of fishes, corallines, encrinites, &c. and in its cavities are found dog-tooth-spar, cubes of purple fluor, acicular crystals of sulphate of strontian, and of oxide of iron. It contains rounded concretions penetrated by petroleum, which sometimes exudes from the rock; it is very hot to the taste, and is used by the masons for an external application, assisted by friction, to remove the rheumatism. Not many of these numerous beds of limestone are quarried; amongst them is the black rock, which is used for paving stones. Many of them will not burn into good lime. Calamine, accompanied by heavy-spar and galena, is found in veins of calcareous spar crossing the limestone: it sometimes covers crystals of the calcareous spar, which frequently has been decomposed, leaving the calamine hollow and in the form of the crystal.* The calamine is sometimes wrought as an ore of zinc. Manganese is found in a vein of ironstone crossing the limestone. The strata alternating with the limestones, are, beds of clay of various kinds, which sometimes are very thin, and schistose; others contain nodules of coral, geodes of iron ore, shells and coralloids. Thin beds of ironstone and quartzose sand are also found; and a bed of coal about two inches thick. (G. T. vol. iv. p. 197.) The whole series of these beds may be considered as belonging to the mountain limestone formation. It is no argument against this, that a seam of coal is found among the strata; since the same circumstance occurs in the vast assemblage of limestone and other beds, forming that part of the great northern coal-field (§ 105) termed the Lead measures, and which are considered as belonging to the same formation.

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* The form of the same variety of calcareous spar has sometimes been found in quartz, which is internally lined by minute crystals of quartz.

§ 141. Mountain limestone ranges round Bristol in almost every direction, forming an irregular kind of basin, of which the northernmost points are the hills about Thornbury. On the east it is well observed in a continuous range at Wickwar and Sodbury; and in a very bold manner at Week, about half way on the upper road to Bath from Bristol. It is wanting on the south-east. This limestone forms a sort of ellipse, and the dip of the strata seems pretty generally to be towards the middle of it. On the north of the ellipse the dip is towards the south; on the east, towards the west, and on the south towards the north. This elliptical basin contains coal. (P. M. Oct. 1814.) The range of mountain limestone reposes on the old red sandstone, which visibly passes beneath it. (§ 151, and Pl. 2. fig. 3.)

§ 142. It might seem consistent in this place to insert some account of the great mountain limestone formation of the northernmost parts of England, underlying, and even forming a part of the great coal-field surrounding Newcastle; but I have been induced to consider this part of the formation in another place—namely, under the head *Coal*, to which I have given a separate head, without considering it as subordinate to the red marle or new red sandstone; in or beneath which, its geological position is known to be. The Independent Coal formation has peculiar characters, inasmuch as the beds of some of the substances with which the beds of coal are connected, contain only organic remains belonging to *fresh-water*; and the chief reason for noticing the limestone formation cropping out from under the Newcastle Coal formation on the west of it, under the head Coal, is that as some parts of it yield coal in abundance; so that the noticing of both formations together, will, as it appears to me, greatly facilitate the comprehension of the whole coal-field.

§ 143. In the 4th volume of the Geological Transactions, there is a communication by Geo. Cumberland, Esq. on the Strata at Whorlbury Camp, a Roman station, at the western termination of the Mendip hills, and on the borders of the Severn sea. The chief object of this paper is the description of a fossil resembling a cane or jointed bamboo, which is found in a schistose sandstone, having its laminæ divided by beds of ochreous marle. In these beds the cane fossil is found; some traces of it are also observable in some thin beds of limestone lying above the marle and sandstone, and separated from them by beds of limestone without organic remains. The cane fossil is rarely obtained more than five inches long, is generally curved, but sometimes is straight, and of all degrees of thickness, from a quarter of an inch to five inches. The ends of the joints are occasionally covered with a thin coat of quartz. Many have their joints filled with hard sandstone, but the centers of the greater part of them are filled with hard white quartz; and where there are cavities, which rarely happens, they sometimes contain crystals of calcareous spar. The strata in which this fossil is found, dip at an angle of about 47 degrees.

OLD RED SANDSTONE.

§ 144. The characters of this rock are thus described It alternates from fine to coarse-grained granular, which latter often inclines to conglomerate; yet in general its grains exceed in magnitude those of the newer sandstone formations. The grains are usually quartz and flinty-slate. Its cement is iron-shot clay, which gives to the whole a reddish colour. Although *the principal character of this sandstone, is the coarseness of its grains and its reddish colour*, yet it sometimes occurs fine-grained, and of a greyish colour. (J. 159.)

§ 145. Assuming these to be the true characters of this rock, it seems very uncertain to what extent it occurs in England. Its locality, according to the Wernerian system, is next to the transition rocks; it is esteemed to be the oldest of the flœtz rocks. A sandstone occurs in many parts of England and in Wales, resting upon and connected with greywacké, one of the transition rocks, which in some respects at least has the characters of the old red sandstone; it is large-grained, and its locality is the same as that of the old red sandstone of the Hartz, which rests on greywacké and greywacké slate. (J. 158.) If it be judged that the old red sandstone occurs in England and Wales, it will I think appear, by the following summary account of what is at present known of its characters, that greater reliance is to be placed on the position of this sandstone for determining its name, than on its perfect agreement in respect of nature and composition, with the old red sandstone of Werner. It must however be remarked, that the rocks of some parts of England which are said to belong to this sandstone, have not been fully decribed; and also that there is much reason for believing that in certain places, particularly in Somersetshire and Devonshire, there is so close an alliance between this rock and the newer red sandstone or red marle, that it will be found extremely difficult to trace the boundary of each, or even to distinguish the one from the other.

§ 146. The western termination of the chalk deposite is found near Honiton in Devonshire. On the west of the chalk, is a red sandstone having an argillo-ferruginous cement; near Honiton it is in the state of a coarse-grained gravel almost entirely disintegrated. It contains rounded pebbles, which are two or three inches in diameter: it then approaches to a conglomerate puddingstone, but near Exeter it assumes the character of an arenaceous sandstone, and becomes more compact and uniform in its texture and composition. This conglomerate is in nearly horizontal strata, which probably extend eastward below the chalk, while in other directions they lie upon greywacké; as for instance, on a hill consisting of that rock, north of Exeter, and overlooking the town (§ 164), and at other places north and north-east of Exeter. On the south and south-west of that place, these sandstones and conglomerates form the surface of the country for several miles towards Ivy bridge, near which also is found slaty and compact greywacké. (G. T. vol. i. p. 98 & seq.) It is however clear that the cliffs at Budleigh Salterton near Teignmouth in Devonshire, which are of considerable height, and those also of Teignmouth itself, though consisting in part of conglomerate, belong to the red marlé or newer red sandstone, since they contain gypsum, which forms a principal characteristic of that rock. (§ 83.)

§ 147. The nature of the conglomerate referred to the old red sandstone formation around Exeter, is best seen by the openings or quarries in its neighbourhood. That of Heavitree is situated about a mile and a half from Exeter on the road to Honiton. It is worked to the extent of a quarter of a mile in length, and to the depth of about 100 feet, in a plane intersecting that of the strata. The rock of this quarry, is a conglomerate evidently stratified: the strata are from six to eight feet in thickness, and dip south-east at an angle of about 15 degrees. As long as this rock preserves the character of conglomerate, it is compact and tenacious; and, according to the workmen employed in the quarry, it hardens more and more by exposure to the air. But as soon as the nature of the stratum changes to an arenaceous sandstone, it is tender and friable. It is very common to see blocks of it in this last state, and sometimes of a great size, included in the middle of the conglomerate. The cement of this rock is argillo-ferruginous; and by itself does not effervesce with acids, as it is easy to prove by making use of pieces of the pure sandstone for that purpose; but it produces so brisk an effervescence from the intimate mixture of calcareous particles, that it might be very easily mistaken for limestone. The substances which enter into the composition of this conglomerate are numerous; and it may first be remarked, that these pieces are of very different sizes and forms, sometimes rolled and rounded, sometimes pointed with sharp angles, from very minute grains to the size of several inches in diameter. There are found in it rhomboidal crystals of calcareous spar and crystals of felspar, most frequently of an opake white, and decomposed; pieces of flint;* greywacké; yellowish limestone; rolled masses of a species of porphyry somewhat resembling the antique, the base of which is a reddish brown colour, not effervescing with acids, and containing numerous, small, and well defined crystals of felspar imbedded in it; pieces of a rock which is itself compounded, having the appearance of a porphyry, the base earthy and including small grains of quartz, crystals of felspar, and pieces of bluish carbonate of lime; and a whitish tender steatite in small angular fragments.

At Upton Pyne, a village five miles north of Exeter, the same conglomerate as that found at Heavitree, occurs beneath a red argillaceous sandstone several feet in thickness. The conglomerate lies on felspar in mass, containing a few laminæ of calcareous spar and some crystals of quartz; forming the roof of a mine of black oxide of manganese which is worked to open day. The red argillaceous sandstone occupies the surface of the country from Upton Pyne to Thorverton, where there are several quarries, all of which are described as being in a *calcareous amygdaloid*, varying in nature considerably in different places. In some parts, the nodules are small, and very closely united in clusters in the base, forming nearly a homogeneous mass, with here and there nodules of a much larger size than the rest, imbedded in it. In other places the nodules are about the bigness of a pea, all of the same size, and consist of rhomboidal sparry laminæ. There are other places where the base of the amygdaloid has the appearance of a sandstone, in which a small number of calcareous nodules are imbedded, which are externally coloured green by the steatite, and exactly resemble those entering into the composition of some of the amygdaloids of Derbyshire, and of the Pentland hills near Edinburgh.* (G. T. vol. i. p. 99 & seq.)

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* If the word flint be here used in its common acceptation; in other words, if the flint found *in* this conglomerate belong to the chalk, it will almost amount to a proof that the rock surrounding Exeter has received a name which does not belong to it, and that it ought to be considered as of a newer formation than the old red sandstone.

§ 148. The stratification of these rocks has been described as being parallel, and of easy inclination eastward in the places before noted. It is however said that the red rock so prevalent about Exeter assumes a great variety of character between that place and Collumpton. In some parts, it is like a stratified gravel; in others, like a compact sand; sometimes the seams are parallel and horizontal, sometimes inclined and curved in various ways; all within a small compass. Sometimes it becomes spongy in its texture, and contains cavities filled with a brown pulverulent powder; sometimes it resembles crumbled schist, or approaches the character of red marle, mixed however with bluish green spots.

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* The whole of this conglomerate, which is on the very verge of the primitive tract of Cornwall, reminded Dr. Berger of that which he observed in other borders of primitive countries near the source of the Rhine, in Switzerland, and on the skirts of the mountains of St. Gothard, where puddingstone forms mountains of considerable elevation. (G. T. vol. i. p. 106.) He likewise mentions the occurrence of similar rocks on the borders of other primitive tracts.

(K. 111.) It may be noticed, that the characters of some parts of the rock of this country, agree remarkably with those of the red rock which have by common consent been referred to the newer formation termed the red marle or new red sandstone. There is one decided characteristic of this latter rock, which is that it contains gypsum, which has been noticed only in one or two places in the red rock of Devonshire, namely, in the cliffs near Teignmouth. (§ 83.)

§ 149. From what has preceded, we may observe that the rock around Exeter has at least two distinct characters, namely, that of a red argillaceous sandstone, and of a conglomerate or puddingstone. The amygdaloid (as it is described to be) occurring in the quarries of Thorverton, is to be considered, as it may be presumed, only one of those various appearances to be expected in a conglomerate. There is nothing in the foregoing pages inducing the supposition that the red argillaceous sandstone and the conglomerate are of different formation. The observations which have been made on somewhat similar rocks, so plentiful in the south-western parts of Somersetshire, would rather induce the belief of their being only varieties of the same rock, of which the conglomerate generally forms the lowest bed.

§ 150. But if the strata surrounding Exeter are correctly designated as belonging to the old red sandstone, there seems equal reason for referring the conglomerate so abundantly found in the south-western parts of Somersetshire, to the same formation, since in many places it is composed of fragments of older rocks. It appears to consist chiefly of the ruin of the stratum on which it lies, namely, the greywacké of that country, and of the limestones which it encloses, or are interstratified with it. The red marle or marly sandstone, connected with the conglomerate of Somersetshire, however, is referable, from its containing gypsum, to the newer sandstone formation, which is commonly termed the red marle. I forbear, therefore, to separate them. (§ 82.)

§ 151. The old red sandstone is however asserted to be the fundamental rock of the mountain limestone formation near *Bristol.* (G. T. vol. iv. p. 210.) This it is said is clearly displayed by the section which some grand convulsion of nature has made of the rocks below Bristol. By following the path on the left side of the Avon, it will be found that the first rock that comes in view after passing the ferry at Rownham, is an indurated sandstone, which is connected with the limestone formation. Limestone then commences, and continues uninterruptedly for about two miles. Opposite Cock's folly it terminates, and then succeeds a puddingstone, or conglomerate, the matrix of which is a greyish white sandstone, cementing rounded pebbles of quartz. In some of the beds, the gravel is so abundant that the matrix is hardly to be perceived; and in other strata, it is so thinly distributed, that the rock better deserves the name of a sandstone than a puddingstone. From the river side, the latter can be traced crossing the road a little below Leigh. It is then for some distance lost, on account of the cultivated state of the country; but in the hills near Pile and St. George's, it is very distinctly seen, and can be followed beyond Portbury. In this route the puddingstone is always seen *dipping under the limestone* agreeably to its inclination. (Pl. 2, fig. 3.) But to return to the river's side. Beyond the puddingstone, which continues for about 200 yards, we arrive at a red sandstone of a fine friable texture and containing spangles of mica. We can follow this rock north-westward from the river, and always see it *sinking under* the puddingstone. It is exposed in many places between Leigh and Portbury, and it is remarked that this rock lies underneath the limestone at Mendip hills in the path leading from Langford to Shipham. Near Ross in Herefordshire the same series occurs. (P. M. Oct. 1814. p. 243.)

§ 152. It is yet very uncertain to what extent the old red sandstone prevails north of Bristol; but it is known that a rock is found in many places as high north as Liverpool, having many of its characteristics. In the "order of superposition," &c. at the end of this volume, it is quoted as occurring near Monmouth, but I believe that no detail of its connection with the neighbouring rocks, or of its extent, have yet been published.

In *Shropshire* also is found a rock which is considered to belong to this formation, though its characters in some parts of it, are of a doubtful kind. It consists for the most part of rather fine grains of quartz, with a few spangles of mica, cemented by clay and oxide of iron. Its colour is generally brownish red, and it has but little cohesion; on which account large tracts of loose deep sand are found in many parts of it. Sometimes it occurs nearly of a cream colour, and is then sufficiently hard to form an excellent building stone: it does not effervesce with acids, and no shells or other organic remains have been found in it. In some places, the loose sand on its surface contains rolled stones of quartz, granite, and porphyry, which also are dispersed over its surface, though they are rarely if ever observed at any considerable depth in the solid rock. There are no sandstone hills in Shropshire which rise higher than 400 feet. In the southern extremity of that county, it rests on elevated strata of greywacké. In general however it does not attain elevations which can be characterized better than by the term gentle hills. (G. T. vol. i. p. 192.) It is now I believe generally agreed, that the rock salt formation of Cheshire, belongs, or is subordinate, to the red marle, or new red sandstone. (§ 77.)

§ 153. Between *Abergavenny* and *Brecon*, particularly as you approach Brecon, the sandstone becomes more slaty and micaceous. In the same neighbourhood we meet with an irregular breccia consisting of masses of limestone and sandstone. (K. 100.)

§ 154. The old red sandstone, 'in its common form of a coarse puddingstone,' is interposed between the limestone formation termed the Lead measuses (§ 116.), and greywacké slate, on the western escarpment of the mountain range, which may be considered as the south-western limit of the Great Coal field surrounding Newcastle (Pl. 2, fig. 4.) and may be traced for several miles. (G. T. vol. iv. p. 106.) Still further north it is found on the eastern base of the Cheviot hills, in the north-west part of Northumberland, which are esteemed to be of primary formation; it there approaches to a conglomerate (G. T. vol. iv. p. 94.) and is interposed between the primitive rocks of the range and the coal formation. (Pl. 2, fig. 4.)

GREYWACKÉ.

§ 155. The Greywacké formation is of considerable extent in the west of England; it is also found in the north, and even the great mountain district of Cumberland and Westmoreland is believed in some degree to be composed of it; but of that tract no accurate details have yet been published; nor am I aware that it has yet been examined with that accuracy which is essential to the proper comprehension of its geological structure. In Wales, greywacké is an abundant rock.

§ 156. In the whole series of mountain rocks, there is not one of which the nature and structure is less generally understood than greywacké. Stones of such opposite character and appearance have received so often this designation, that it is at length become almost a bye-word:—if the character of rock be not very intelligible, it is not uncommon to inquire, with a smile, if it be greywacké. Its characters are thus described by Jameson:—It is a kind of sandstone, but very different from any of those that occur in the flœtz period. It is composed of grains of sand, which are of various sizes, and sometimes even approach in magnitude to rolled masses. These are connected together by a basis of clay-slate, and hence this rock derives its grey colour and solidity. These fragments are sometimes quartz, sometimes a kind of indurated clay-slate, and sometimes flinty-slate. (J. p. 150.) Brochant says that Greywacké is a sandstone (grès) composed of grains of quartz, flinty slate, and clay-slate, agglutinated by an argillaceous cement of the nature of clay-slate. The grains are sometimes small, and even very small; sometimes of the size of a nut. (B. vol. ii. p. 588). It is therefore clear, that one essential character of this rock is, that it is a sandstone; that it must be expected to vary greatly in appearance is obvious from the foregoing descriptions; but if we strictly attend to these, we shall run the less hazard of confounding other rocks with those belonging to this formation, difficult of distinction though they often be. Greywacké is commonly solid, if not compact; and it is interstratified with slates, which therefore are termed greywacké slates; but the characters of these often approach those of clay-slate, possessing even its silky lustre, so that it is frequently impossible to decide by a hand-specimen to which it belongs. This circumstance clearly shews, that though a knowledge of mineralogy is in most cases essential to the proper knowledge of rocks, especially of the primitive and transition classes, it is not always competent to decide the class to which they belong. The most patient investigation in the great field of nature, among rocks decidedly in their natural position, is sometimes alone capable of this.

§ 157. In the 3d volume of the Transactions of the Geological Society there is a very interesting memoir, by Leonard Horner, Esq. on the geology of the south-western parts of Somersetshire; from which the principal part of the following pages, relative to the greywacké of that county and of Devonshire, is extracted. In Devonshire, greywacké is termed *Dunstone* and *Shillat.*

The Quantock hills, Grabbist hill, Croydon hill, Brendon hill,* and some others on the west of them in

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* The highest point of the Quantock hills is 1270 feet above the sea: Grabbist hill is 906 feet high.

Somersetshire, appear to consist chiefly of greywacké, which in some places is interstratified with limestone. A great bed of limestone is said to traverse the Quantock hills (Annals Dec. 1817). But some of the vallics and low grounds, and even the rock forming the coast of the county, consists in some places, not of greywacké, but either of the lias limestone (§ 73), or the red marle. (§ 82. The mountainous part of the county, however, has a smooth, undulating, and rounded outline, no where rugged, or presenting any cliffs or precipitous faces, except on the sea-shore, where sections have been formed probably by the action of the tides. The whole country is so covered by vegetation, either in the form of heath and turf on the high land, or of the more luxuriant productions of the vallies, that very few opportunities occur in the interior, of ascertaining the nature of the rock on which the soil rests; but the cliffs on the sea-shore afford such an ample field for studying the mineralogical character of the country, that the scattered observations in quarries, may be more strongly relied on and more easily connected. (G. T. vol. iii. p. 340.)

§ 158. The mountainous part of the north-western district of Somersetshire, is formed of a series of rocks differing very materially in mineralogical characters, but which the repeated alternations of the several varieties, and the insensible gradations that may frequently be traced of one into another, connect into one common formation. A great proportion of these have the structure of sandstones, the component parts varying in size from that of mustard-seed to such a degree of fineness, that the particles can with difficulty be discerned. Quartz and clay are the essential component parts of all the varieties, but in different proportions. The quartz in some instances prevails to the entire exclusion of any other ingredient, forming a granular quartz rock: it is more abundant in the aggregates of a coarse grain; clay being the chief ingredient in those of a close and fissile texture. They have all an internal stratified structure; which is less apparant in those of a coarse grain (and in a cabinet specimen scarcely discernible), but which becomes gradually more distinct as the texture becomes finer; and at last the rock graduates into a fine-grained slate, divisible into laminæ as thin as paper, and having the smooth silky feel and shining surface of the clay slate of a primary country. Alternations of the fine-grained slaty varieties with those of the coarsest structure in many successive strata, and without any regularity of position, are of constant occurrence, and frequently without any gradations from one structure into the other. In some instances portions of slate are contained in the coarse grained varieties. Scales of mica are frequent, and they all contain oxide of iron in greater or less proportion, and to the different states of this oxide their various colours are, no doubt, to be ascribed. The prevailing colours are reddish brown and greenish grey, and there are many intermediate mixtures of these colours. Some of the slaty varieties are of a purplish hue, and this is occasionally spotted with green. Of the specimens I collected, those of a coarse grain and of a dark reddish brown colour, do not effervesce with acids; those of a pale reddish brown colour, and of a greenish grey colour, all effervesce, and some of them briskly. None of the varieties of slate shew any signs of effervescence. The magnet was not affected by any one of the series. No trace of any organic body was discovered in either variety, but in many places great beds of limestone full of madrepores, are contained in the slate; the limestone and slate towards the external part of the beds being interstratified. Veins of quartz which are often of great magnitude, are of constant occurrence, being sometimes accompanied by calcareous spar and ferriferous carbonate of lime; veins of sulphate of barytes are not uncommon. Thin layers, composed of quartz, chlorite, and ferriferous carbonate of lime, are often interposed between the strata of slate, and pyrites is sometimes disseminated through the mass of the rock. Copper, in the state of sulphuret and of malachite, and veins of hematite, are frequently found, and nests of copper ore of considerable magnitude, have been found in the subordinate beds of limestone. (G. T. vol. iii. p. 342.)

§ 159. Near the surface, the strata of greywacké are traversed by cracks, which make the rock, as soon as it is removed from its bed, break down into polygonal fragments of various dimensions. And in some places, especially where the slaty varieties prevail, the ends of the inclined strata as they rise to the surface, become either vertical, or are very much twisted. These twistings are not curved, but angular, with a fracture at every angle, and are concluded to have taken place after the induration of the rock. The most remarkable instances of these angular contortions are to be noticed in the lanes between the villages of Exmore and West Monckton, and the other roads which cross the south-eastern ridges of the Quantock hills. In the neighbourhood of Adsborough, and in the lane leading to Tarr near Kingston, the ends of the strata of slate are covered by horizontal beds of red argillaceous sandstone and of conglomerate. (G. T. vol. iii. p. 346).

A small quantity of copper ore was taken some years ago from one of the branches of the Grabbist hill; and also at Perry near the northern extremity of the Quantock hills. It may be questioned whether this circumstance is not demonstrative of some analogy between the greywacké of this county, and the metalliferous clay-slate of Cornwall. (G. T. vol. iii. p. 349.)

§ 160. North hill, which extends along the shore westward from Minehead to Porlock, forming a very bold and precipitous coast, affords the best opportunity of studying the greywacké formation. At Greenaley point, about a mile west of Minehead, there are very lofty sections, where the alternations of the different varieties may be distinguished, and where there are also very good examples of those curvatures, which, in this formation, are of such frequent occurrence. Strata that run for some distance in a horizontal line suddenly turn up into a vertical position, at other times they assume the form of an arch or a succession of great curves.

It is hardly necessary to say that these rocks could not have been deposited in the forms they now exhibit, and it is pretty evident that the flexures must have taken place while the rock was in a plastic state; for there is no fracture at the bendings, nor any interruption to the continuity of the mass. Similar curvatures are to be seen at Hurstone point, the western extremity of North hill. These appearances are so well known that drawings of them are unnecessary: they are very analogous to those observed by Mr. Conybeare in the same rocks on this coast, some miles westward, and represented in the 33rd and 34th Plates of the 2nd volume of the Geological Society's Transactions. (G. T. vol. iii. p. 345.)

§ 161. The limestone connected with the greywacké of Somersetshire and Devonshire, appears in several places in the form of beds or masses, interstratified with the greywacké. There are numerous quarries along the eastern side of the Quantock hills in Somersetshire, in which the beds or strata of limestone are enclosed in slaty greywacké. As flattened spheroidal masses of similar limestone are frequently found completely enveloped in the slate (G. T. vol. iii. p. 350), this circumstance seems to point out that the limestone is not always in regular strata, conformable with those of the greywacké slate above and below them. At Allercot, about four miles south of Minehead, the principal bed of limestone is 30 feet thick, and is of a bluish grey colour variegated with red, of a crystalline structure, and full of small laminæ of calcareous spar disseminated in detached spots through the mass, which are conjectured to be the remains of organized bodies. In the extensive quarries on the eastern side of the Quantock hills, many parts of the bed of limestone are almost entirely composed of madrepores, particularly towards the exterior. Circular bodies composed of crystalline plates of calcareous spar are also enclosed in this limestone, but no shell has been discovered in it. (G. T. vol. iii. p. 351.) These appearances sufficiently prove that this limestone is not of primitive formation.

§ 162. The limestone occasionally contains copper, a large quantity of which was found in it some years ago at Doddington near Nether Stowey, in a black slaty limestone. It consisted chiefly of the green carbonate and of yellow copper ore. In it also are found caverns, so frequent in limestone, varying in width from half a foot to five feet, and of a depth varying with the depth of the bed: large stalactites of carbonate of lime hang from the roofs of some of these caverns, and their formation is still going on. (G. T. vol. iii. p. 352.)

§ 163. Near Ilfracombe in ***Devonshire***, beds of limestone also occur in greywacké-slate, having decided indications of enclosing organic remains. The greywacké-slate, in a cabinet specimen, is not distinguishable from the clay-slate of primitive countries; but as the beds of limestone which it encloses contain organic remains, it clearly shows that the slate, as well as the limestone, is a secondary rock. (G. T. vol. iii. p. 355.)

§ 164. Thorverton quarry is seven or eight miles north of Exeter in Devonshire. In going to it by Cowley-bridge, on the summit of a hill which overlooks Exeter, and is almost close to the town, the greywacké is met with *in situ*. It is of a greyish colour, with very distinct and separate grains, breaking spontaneously into rhomboidal fragments; it is harder in some places than in others; when tender it splits in the manner of slate, and assumes quite the character of that species of rock. It occurs in strata dipping north-west at an angle of about 70 degrees. The same greywacké formation is met with north-north-east of Exeter on the road to Bickleigh, Silverton, Rew and Cross-hill; at Cross-hill the direction and inclination of the strata are very distinctly seen. From Cowley-bridge the greywacké extends as far as the neighbourhood of Upton Pyne; but in this district it can only be distinctly seen on the summits of the hills; it is lost (as in Somersetshire) in the bottoms of the vallies, which consist of red argillaceous sandstone. This is particularly the case at Upton Pyne, a village five miles north of Exeter on the right bank of the Ex. At this place there is a mine of black oxide of manganese worked in open day, which affords good opportunity for observing the strata, and the nature of the rock. The red argillaceous sandstone, where the mine is excavated, forms a stratum several feet in thickness from the surface; below this is a conglomerate puddingstone, the same that is found in the parish of Heavitree (§ 147), but quite disintegrated; then a reddish compact felspar in mass, containing a few laminæ of calcareous spar, and some crystals of quartz. This last rock forms the roof of the mine. Several varieties of the black oxide of manganese have been met with, together with ferruginous carbonate of lime. The red argillaceous sandstone forms the surface of the country from Upper Pyne to Thorverton, where there are several quarries, all in the same rock; viz. a calcareous amygdaloid (§ 147), the nature of which, however, varies considerably in different places. (G. T. vol. i. p. 101.)

The limits of the greywacké of Devonshire have not been ascertained. It is believed to rest upon clay slate on the west; but its connexion with that rock is so intimate, as to render it difficult to determine their actual junction. A rock, which is by some geologists esteemed to be the old red sandstone, also occurs in Devonshire (§ 146), but the places of its connexion with the greywacké formation, do not appear to have been accurately ascertained.

§ 165. In *Cornwall*, rocks belonging to the greywacké formation are to be found; but their extent in that county is not known. If however we were to place implicit confidence in the report of Dr. Berger (G. T. vol. i.), we should admit that the granite range of that country is flanked both on the north and south by greywacké (§ 184.) The rock of these tracts is however generally considered chiefly to belong to the clay-slate formation; though certainly not without exception.

A specimen of rock which prevails all around Probus, and especially between it and Grampound, has lately been presented to me by Dr. Paris. It appears generally to possess the decided characters of greywacké slate; but with it is associated a slate, on, and in the crevices of which, so great a proportion of mica is prevalent, that it might of itself be classed as a mica-slate. Greywacké is also known to exist in the western part of the county, south of the granite range; and there is reason for believing that it prevails on the northern coast, in continuation of the greywacké of Devonshire, since the contortions which may be said to be characteristic of this rock are visible as far as Padstow, and I believe beyond it on the west.

§ 166. Greywacké-slate is the rock on which rests the mountain limestone formation of *Northumberland* (Plate 2, fig. 4,) and is there also, as well as in the west of England, in connexion with the old red sandstone, which is interposed between the limestone and the slate (§ 121); which on its western side abuts against greenstone (primitive trap), (Plate 2, fig. 4.) Still further north, greywacké appears on the south-western side of the primitive range called the Cheviot hills, and is fine-grained in structure; but the slates there quarried do not stand the action of the air. (G. T. vol. iv. p. 94.)

§ 167. In the greywacke-slate of *Shropshire*, and chiefly on the western side of one of the highest hills called the Stiper-stones, the principal lead mines of Shropshire occur. In that called Snailbach, that rare mineral the carbonate of barytes, is found in irregular masses weighing from 40 lbs. to 2 or 3 cwt., imbedded in sulphate of barytes. (G. T. vol. iv. p. 440.)

§ 168. In *Wales*, the greywacké formation is said to occupy a large tract, and near its eastern borders is in some places associated with the old red sandstone; but the extent of this rock has not been ascertained. Within its range there are several mountains 1000 feet high. The Cradle mountains, situated in the same district, and on the south-east of Brecon, are 2545 feet above the level of the sea. A slaty rock is described as occurring on Snowdon, which encloses impressions of shells, (G. T. vol. iv. p. 425.) A specimen from near the summit of that mountain, in which the cast of a shell is very visible, and which is in the possession of Captain Colby, appears decidedly to belong to the greywacké formation; and it is of a schistose structure.

TRANSITION LIMESTONE.

§ 169. Transition Limestone may be said not to be very plentiful in England. In two or three instances it has been observed forming masses, but the nature of their connexion with other rocks has not been discovered; in other places it has been found forming beds, most of which are of no considerable magnitude, and which are included in those rocks that have been referred by the consent of several observers to the greywacké formation. This geological position suffices at once to refer the limestone so imbedded, to the class of transition rocks, and to determine that it is subordinate to the greywacké formation. Another character of these beds is, that the organic remains they enclose consist chiefly of madrepores, which are esteemed to have been one of the first links in the great chain of animated being. Limestone bearing this character occurs in beds enclosed in the greywacké of the Quantock hills in Somersetshire (§ 161), and in greywacké on the northern coast of Devonshire. (§ 163.)

§ 170. A rock, which may be supposed to belong to this formation, is found a short distance on the north-west of Bridgewater in *Somersetshire*. It occurs in the form of an insulated hill, rising 232 feet above the level of the surrounding plain, which is of the red marle. This hill is called Cannington park. It consists of a highly crystalline limestone of a pearl grey colour, having a very close grain, and when struck, giving a ringing sound like that of glass. No organic remains have yet been discovered in it, but it contains some veins of calcareous spar; and also veins of red sulphate of barytes, enclosing copper pyrites and green oxide of copper. It yields a very pure white lime. (G. T. vol. iii. p. 365.)

§ 171. It is generally agreed that the limestone forming the left bank of the Plym, near Plymouth in *Devonshire*, is transition. Some of it near Plymouth has been found to contain shells. (G. T. vol. iv. p. 410.) Still further in the west of England, thin beds of limestone are found alternating with *killas* in Veryan in *Cornwall*, and in the neighbouring parishes. It is of a blue colour, and contains veins of a calcareous spar. If the *killas* should on examination hereafter prove to be a clay-slate, the limestone it encloses will doubtless be considered as primitive; but if it should belong to the greywacké formation, the limestone will be esteemed to belong to the class of transition rocks.

§ 172. Transition limestone has been described as occuring in the form of a thin bed or two of a blackish colour, lying in the greywacké slate forming the fundamental rock of the limestone formation of the north of England, and which constitutes the older part of the great coal-field of *Northumberland* and *Durham* (§ 166.)

SIENITE.

§ 173. Sienite, and that variety of primitive trap which is termed greenstone, both consist of felspar and hornblende; and the chief difference between them seems to be that the felspar of sienite is red or reddish, while that of greenstone is whitish or greenish. This rock is very sparingly found in England. It has been noticed near Mount Sorrel in Leicestershire, and in the Malvern hills, at both of which places it is associated with granite; in the latter of them, it is frequently so considerably decomposed, as almost to have lost its peculiar characters.

At Mount Sorrel, and at Grooby at the southern end of Charnwood forest in Leicestershire, slates of various kinds appear, and are described as being closely connected with the sienite without any order of superposition, but apparently placed side by side. At Mount Sorrel, granite is said to accompany these rocks; which, I believe, have not yet been adequately examined; the whole group merits the attention of the acute mineralogist, even at the risk of his incurring the penalty of using some of the German names, greenstone, hornstone-schistus, trap-formation, &c. (F. p. 154.)

SERPENTINE.

§ 174. This rock occurs forming a considerable tract of country south of Helston in Cornwall, called Gonelly Downs, and extending nearly to the Lizard Point. The precise geological situation of this rock has not been determined; in other words, geologists have not agreed decidedly in referring it either to the class of primitive or transition rocks. If however it be an accurate description of primitive serpentine, that it is chiefly of an uniform green colour, the serpentine of Cornwall, which is of various shades of green and red intermixed, ought rather to be considered as a transition rock. Clay-slate is the rock which succeeds it on the north (though their precise point of contact and relative geological position have not been ascertained,) and which therefore interposes between the serpentine, and the range of granite hills. Near the Lizard, serpentine encloses veins of soap-stone; which, when first raised, is so soft as that it may be kneaded like dough; but after exposure to the air it becomes friable, owing perhaps to its parting with a considerable portion of the large quantity of water it contains. It is used, I believe, chiefly in the porcelain manufactory at Swansea. It also encloses and passes into asbestus, and small quantities of native copper have been found in it. Rocks enclosing shiller spar and diallage metalloïde are connected with it, as well as some others which bear a strong affinity to those of the trap formation.

Our knowledge of this singular district is extremely scanty, but an interesting communication on the subject will shortly appear in the Transactions of the Royal Geological Society of Cornwall.

Serpentine does not occur, I believe, in any other part of England.

TRAP.

§ 175. Primitive trap occurs but sparingly in England; only some of its numerous varieties are found, and those are not known to form any very considerable tracts of country. In Wales, a considerable proportion of some of the mountain ranges consists of primitive trap. There are however in England rocks which are described as belonging to the trap formation, and which from their geological position may be considered as flœtz rocks. Some of these are either interstratified with mountain limestone, or are found filling up the dykes traversing either the mountain limestone, or the numerous beds forming the great coal-fields of England which rest upon it; the trap of some of these dykes is however of doubtful origin; that of others, which has in part been described as a basaltic rock, if an opinion may reasonably be formed from the remarkable facts connected with the history of these dykes, we are almost necessarily led to conclude must have resulted from igneous fusion. (§ 122.)

§ 176. There appears to be some reason for assuming that at least a proportion of the primitive range called the Cheviot hills, in the north-western parts of Northumberland, consists of some varieties of trap rocks. On the eastern side of this range, the old red sandstone occurs; on which reposes a limestone formation consisting of beds of that variety termed mountain limestone, alternating with beds of sandstone, &c. in which are found beds of coal; the whole constituting the most northerly part of the great coal-field surrounding Newcastle. (§ 95.) The greatest elevation of the Cheviot hills is 2642 feet above the level of the sea. The higher parts of these mountains being covered by peat moss, and their lower acclivities with alluvial soil, it is not easy to trace the exact line of separation between the porphyritic rocks of which they consist, and the secondary country bordering them. But we may be led to conclude that the summit of this range consists of primitive rocks belonging to the trap formation, since the masses resting upon it consist of felspar porphyry enclosing crystals of reddish white felspar, and occasionally minute crystals of hornblende; and among the rude masses and blocks which lie scattered by the sides of Wooler-water at the base of the range on the east, are found porphyritic and granitic sienites. Hornblende rock is by no means uncommon among these hills. Housy crag, which rises near Langley ford in the valley between Cheviot and Hedgehope, a summit of the same range, but of less elevation, is composed of a coarse-grained variety of hornblende rock; and the perpendicular cliffs of Hellhole, on the opposite side of the Cheviot, consist also of the same rock. (G. T. vol. iv. p. 94.) These facts are thus noticed without any certainty that the porphyritic rocks found as above described actually belong to the class of trap rocks, but the slight information that has been given respecting them, renders it somewhat reasonable to refer them to it, or at least difficult to assign them to any other.

§ 177. The variety termed Greenstone, is described as occurring in the north of England, and in a situation not very dissimilar to the preceding. The south-western termination of the great northern coal-field rests, like the northern, upon the old red sandstone, reposing upon greywacké, the western side of which abuts, as it were, against a range of greenstone several miles in length; (Plate 2, fig. 4.) This greenstone is, in some places, dark and compact, red externally, and very ferruginous. Knock pike and Dufton pike, two lofty and nearly conical hills on the north-east of Appleby in Westmoreland, consist chiefly of this greenstone; in which a thin bed or two of blackish transition limestone is visible near the south base of Knock pike. (G. T. vol. iv. p. 107.)

§ 178. A trap formation of considerable extent occurs in *Shropshire*. It constitutes the great mass not only of the Wrekin, but also the Lawley, Caer Caradoc, Ragleath, and Hope Bowdler hills. This great trap deposite is described as resting on transition, or perhaps the newest primitive clay slate, which breaks out to-day in the streets of Church Stretton. One of the characteristics of this trap is, that its position is not conformable with the clay-slate on which it rests; nor does it correspond with any of the traps described by mineralogical writers. The great mass of the rocks of this formation have been divided under two heads, Felspar rocks and Greenstone rocks.

The *Greenstone* rocks lie under the felspar rocks, and their essential component ingredients are dull green hornblende, and greenish or reddish felspar; and being subject to decomposition, they are readily distinguished by their smooth depressed verdant surface from the felspar rocks, the surface of which is bare and craggy. When the greenstone is very crystalline, it contains only iron pyrites; but when the hornblende and felspar are more intimately mixed, the rock becomes amygdaloidal, and contains globular concretions of felspar, quartz, calcareous spar, hæmatite, zeolite, and actynolite. A rock of this kind, and of great beauty, occurs on Caer Caradoc.

The basis of the *Felspar* rocks is a clay-stone or compact felspar. That variety which occurs on the summit of Caer Caradoc, is a cellular claystone, the cavities of which vary in size from a small almond to a pin's head. They are all very much compressed, are lined with minute crystals of quartz mixed with a yellowish green earthy matter, which is perhaps decomposed actynolite. A variety of this rock is found at the top of the Wrekin.

On the felspar rocks occur, in some places, other beds which are interposed between them and the limestone formation of Shropshire, as claystone or compact felspar, quartz-grit, and slate-clay, on which reposes the limestone (§ 126). (G. T. vol. i. p. 206, & seq.)

§ 179. Some varieties of trap rocks are said to accompany the granites of the Malvern hills in *Worcestershire*, and of Mount Sorrel in *Leicestershire*.

At Micklewood in *Gloucestershire*, to the east of the road to Bristol, and within two miles of Frampton, is a mass called the *Old rock*, which rises perpendicularly to the height of about 30 feet, is less than 300 yards wide, and extends in the other direction about a quarter of a mile. It is found again to the north-east of the first mentioned place, dipping to the east beneath the surface.

The Micklewood rock has an amygdaloidal character, containing plain and striped chalcedonies, and numerous fungiform or irregularly cylindrical masses, composed of iron spar. Those masses are often two feet in length; the chalcedonies vary from one to twenty inches in diameter, and are nearly all of the same shape, convex above, and concave beneath. (G. T. vol. iv. p. 444.)

§ 180. Trap is very sparingly found in the western counties of England. A bed of greenstone, in the composition of which there is much steatite, is described as being included completely in argillaceous schistus, near Torr point on the south coast of *Devonshire*; though small in extent it is quarried for building. Other beds of the same kind are visible in the same neighbourhood. A bed of the same rock is also said to lie in clay-slate near St. Mary Tavy. (G. T. vol. i. p. 115.) These I believe are the only instances hitherto noticed of the occurrence of this rock in the west of England; but some of the rocks near the Lizard point in *Cornwall*, partake greatly of the characters of greenstone and greenstone-slate.

§ 181. Trap rocks constitute a considerable proportion of the primitive mountain ranges of *North Wales.* No part of that country has yet been sufficiently explored; nor is it, I believe yet known, to what extent rocks of the trap formation occur in it; consequently their boundaries have not been defined.

In North Wales there are two principal mountain ranges, whose direction, like that of primitive ranges in the general, is north-east and south-west. Of the northernmost of these, the summit of Snowdon forms the most elevated point, and that of Cader Idris of the other.

The upper part of Snowdon consists of cliffs of different heights, rising one above another. Its highest peaks are said to be composed of porphyritic rocks belonging to the trap formation, passing into nearly compact or schistose hornblende. Near the summit, however, there is reason to believe, that schistose rocks belonging to the greywacké formation are found, enclosing the impressions of shells. (§ 186). The sides of the Snowdon chain are covered by rocks generally partaking of the schistose character, and although their precise nature is not known, it is understood that the prevailing rock of North Wales is clay slate or argillaceous schistus. The outgoing of these rocks becomes lower and lower, as they recede more and more from the elevated trap formation forming the summits. Upon the north of Snowdon, on the banks of the Menai, separating Anglesey from North Wales, mountain limestone succeeds the clay slate. The latter rock may be said to be the prevailing rock of Anglesey; granite occurs near its center, and mountain limestone towards its southern side. On the north-eastern termination of the Snowdon chain, the greywacké formation makes its appearance, and is succeeded by mountain limestone. (See Map).

The mountain chain of which Cader Idris forms the most elevated part, consists of many lofty peaks, and includes the mountains called the Arrans and Arennegs. The peaks and summits of this, as well as of the Snowdon chain, are composed of rocks of the trap formation, which are succeeded on the north-west by slates of various kinds extending to Snowdon. The same rocks form the country on the south-east of this chain, and are the prevailing rocks of the greater part of Wales south of it. On the north-east occurs greywacké; to which succeeds limestone, and afterwards coal; the same order prevails in the termination of the slate formation in South Wales; greywacké succeeds; then limestone, on which reposes the vast coal deposite, bordering the Bristol channel. Limestone occasionally makes its appearance in the slates of the country south of the Cader Idris chain, and mostly bears the characteristic marks of mountain limestone, but sometimes of a transition rock. It is important to mention that the porous appearance assumed by some rocks which occur on the flanks of Cader Idris, have induced some travellers to suppose that mountain, or at least some of its rocks, to be of volcanic origin. This opinion was the more plausible, and seemed to receive strong corroboration from the appearance of a large hollow, high up the mountain, now occupied by water, and forming a lake overlooked by a steep cliff, greatly resembling the crater of a volcano. It is however now decidedly believed that no trace of volcanic matter is to be found on the mountain.

The upper part of the steep cliff just mentioned forms the summit of the mountain; it consists chiefly of immense columns of highly crystalline greenstone, rising at a considerable angle from beneath a ruin, which lies between their base and the lake beneath. The height of these cliffs is about 1100 feet. At least the lower half is occupied wholly by the columns of greenstone: similar columns, but of less size, appear above, and these are interstratified with slates, greatly resembling primitive clay-slate, lying at right angles with the columns of greenstone. The southern flank of the mountain consists chiefly of slates, lying at almost every possible angle in different places, rendering their stratification very difficult of comprehension. On the north of the summit, and between the lake at its base and the town of Dolgelly, an immense range of stoney mountains stretches nearly east and west. These consist chiefly of greenstone, which commonly is columnar, sometimes slaty. The profile of these rocks in the distance, is precisely that which gave the name to the trap formation: it resembles steps or stairs; the intervening hollows of which are sometimes partially filled by slates. Some of the greenstone of this range encloses crystallized carbonate of lime, and therefore assumes the character of a porphyritic rock. In many places it may be observed that the carbonate of lime has been decomposed, leaving cavities: and this circumstance, together with the decomposition of the iron, forming an ingredient of the hornblende, which often abounds, has given to the rock a cellular and rusty appearance, which has induced the suspicion of its being actually the product of a volcano. A blow of the hammer will in most cases expose the truth.

Though the southern parts of Wales are said to be chiefly occupied by the greywacké formation, trap rocks are found near St. David's head, the country around which consists of rocks of that description. That of St. David's head is considered to be primitive. The predominating colour is brownish green. The general character of the rock is crystalline, but the felspar rarely if ever occurs in distinct crystals, and even the hornblende, though usually the most accurately defined of the two, is sometimes not discernible from the felspar. The mass has sometimes even the appearance of a mechanical deposite. In some instances the character is so extremely equivocal, as to leave the judgment in a very difficult state of suspense. (G. T. vol. ii. p. 80). This indeed is no uncommon circumstance in primitive rocks: their characters are not always so decidedly marked as to leave in the mind of the observer no doubt of their precise nature. Another difficulty is also very common; their transitions are gradual and frequent, especially among the trap rocks. On the side of Cader Idris I observed a rock which on one side appeared to be that variety of primitive trap which is termed greenstone-slate: by degrees the hornblende was lost, and the felspar became compact, and enclosed crystals of quartz. On one side, therefore, this rock had the appearance of greenstone-slate, and on the other of a porphyritic felspar, although it was only three feet wide, and was without a crevice.

§ 182. We must not however here pass by, without some notice, those obscure and scarcely intelligible rocks, which in England are found interstratified with the mountain limestone connected with the great northern Coal-field (§ 96), and with the same limestone in Derbyshire, which is connected in a similar manner with the Coal-field of that county (§ 132); and also those rocks which, in Shropshire and in Staffordshire, are still more intimately connected with the coal of those counties. These rocks have received the names of trap, basalt, greenstone, amygdaloid, and toadstone, almost indiscriminately, and at the pleasure of those who have described them. (§ 131). When however it is said that the foregoing names are given indiscriminately to these rocks, it is not thereby pretended to assert that they are all precisely of the same nature or origin; but such as are found generally speaking under similar geological circumstances, may be suspected to belong to one class. Their composition is not always the same; and some of those which have been most particularly described, are found to exhibit very different characters in proximate parts of the same bed, especially that of Derbyshire. The *Toadstone* of Derbyshire (§ 134), and the *Basalt* of the north of England (§ 121), are interstratified with mountain limstone: the *Greenstone-trap* of Shropshire lies between it and the coal strata (§ 181); and *Trap*, *Green rock*, or *Greenstone*, lies between the strata constituting the Coal formation at Birch hill colliery, near Walsall in Staffordshire. (§ 128). In the northern Coalfield, *basalt* is found in veins or dykes, traversing the beds of Coal, and all those beds of sandstone and other substances with which they are interstratified, and which thence have received the name of Coal-measures, producing the most extraordinary contortions and dislocations in the strata, and the most strange effects upon the coal. (§ 122).

In the 'Order of Super-position,' &c. to be found at the end of this volume, all the rocks just noticed are included under the term *Flœtz Trap*: and it may be assumed that the trap of Shropshire (§ 178) lying on clay-slate, may, from its *unconformable* position with that rock, be also included in the same class.

CLAY-SLATE.

§ 183. This rock occurs extensively in the northern and western parts of England. In the first, it forms a large proportion of the mountainous district of Cumberland and Westmoreland, but this interesting tract of country has not yet been sufficiently explored to enable us to trace its boundaries. Skidaw and some of the neighbouring mountains consist chiefly of it, and the plumbago of Borrowdale is described as occurring in a mountain of the same nature. In the western part of England it reposes on both sides of the great granitic range (§ 195), extending from the middle of Devonshire to the extremity of Cornwall.

§ 184. Clay-slate, there is great reason for believing, has often been confounded in geological description, especially in that of the western counties, with greywacké, that least intelligible rock of the whole mountain series of England; and Dr. Berger has even gone so far as to give the name of greywacké to the whole of the clay-slate of *Cornwall*; but though it is not to be denied that greywacké is found in that county, (§ 165), yet almost the whole of the immense deposite reposing on the granite range, both on the north and south, is I believe considered to belong to the clay-slate formation : and it is in this tract that the principal mines of Cornwall, both of tin and copper, are situated.

§ 185. The clay-slate of Cornwall is termed *Killas* by the miner. Its stratification is very distinctly seen at the passage of the Tamar near Calstock, and of the Tavy near Beer Ferris, as well as at many other places on the south of the central range of granite, and on the coasts; and it is very clear that the general dip of its strata is about south-east, at an angle of about 70 degrees; while on the northern side of the granite, the dip of the clay-slate is nearly north-west.

It has been remarked (G. T. vol. ii. p. 499) that the killas of Cornwall has generally the silky character ascribed to clay-slate. It is traversed almost throughout its whole extent, by frequent veins or rather dykes of a porphyritic rock, which forms one variety of the *Elvan* of the Cornish miner, and which does not occur either in the *Dunstone* or *Shillat*, (the greywacké) of Devonshire. It has been found to contain at St. Agnes, the topaz, and in various places, tourmaline and the garnet: the dykes are frequently occupied by chlorite, by mica, and by crystallized felspar. A considerable part of the tin of Cornwall is obtained from the killas, and the grey ore of cobalt has repeatedly been found in it. All these minerals have usually been considered as characteristic of the earlier rocks, and none of them are, I believe, stated by the writers of our most esteemed mineralogical systems, to occur in that to which they assign the name of greywacké.

§ 186. In the preceding section, the veins or dykes of porphyritic rocks, termed by the miners *Elvan*, have been mentioned as characteristic of the clay-slate formation of Cornwall. These have not been thoroughly investigated; for since the miner attends only to those points which in his own estimation tend to benefit his occupation, without recording the curious facts which daily offer themselves to his notice, no account of these extraordinary dykes, termed by the miner *channels*, is to be found.* It may however prove interesting to notice them generally. In the mining district of Cornwall, they are commonly found in killas, rarely, I believe, in granite; which, either in its natural state or when decomposed, is termed by the miner *grouan*. Their common direction on the surface is east and west; and they generally dip beneath it towards the north; frequently very rapidly, that is to say, at a small angle with the horizon. These beds or channels vary from a few, to 50 or even 80 fathoms in thickness, and in some cases are continuous through a long tract of country, as is the case with metalliferous veins, but with which they have no analogy. The veins both of tin and copper generally pass through them, but are commonly narrower when in the elvan, than when in the superincumbent and subjacent rocks, which are usually clay-slate. The channels have sometimes a granitic aspect, but are commonly porphyritic; the base being a kind of hornstone, or felspar, and the imbedded substances crystals of quartz or felspar.

On the northern coast of Cornwall, Elvan is described as occurring in beds and veins of every possible thickness, from forty feet to half an inch, sometimes overlying, but more often traversing the killas in various directions, and under such circumstances as are apparently irreconcilable with any other theory than that which supposes them to be of *contemporaneous formation* with the rock enclosing them. These elvans are for the most part of porphyritic structure, the base being in most instances a very minute aggregation of quartz, pale chlorite, and possibly some felspar: the first of these is usually the predominant ingredient, the imbedded substances are felspar, quartz occasionally crystallized in small double hexagonal pyramids, and chlorite in small patches. (G. T. v. iv. p. 402.)

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* We may however hope that, in the future, the new and curious facts which the Cornish mines continually present, will be made public. In the first volume of the Transactions of the Geological Society of Cornwall, we have reason to expect an account of the *Channels of Elvan*, which are of frequent occurrence in the mining part of the county.

§ 187. The neighbourhood of Tintagel on the north coast of Cornwall, and six miles on the north-west of Camelford, is famous for its quarries of roofing slate of excellent quality. The slate is much freer from curvatures and contortions than that along the coast to the eastward of it; it contains no elvan dykes. In its veins are found quartz, rock crystals of great transparency and beauty, calcareous spar, chlorite, and in some instances adularia, but no metalliferous ore. It is however remarkable that a slate has been found bearing the impression of shells, representations of which are given in Plate 25 of the 4th volume of the Geological Transactions, but they appear to be rare; and in the greywacké slate of Snowdon (§ 168), a similar impression has been noticed. (G. T. vol. iv. p. 425.)

§ 188. On the northern part of the coast of Cornwall, where the newer formation of granite rests on the clay-slate, and where the latter rock is intersected by elvan veins and beds, in the neighbourhood of Clegga point, (§ 201), the slate occasionally presents singular curvatures; in many places it passes into chlorite-slate, and in the immediate neighbourhood of the elvan dykes, it usually presents, either a highly crystalline form of that rock, or such an intermixture of it with quartz and felspar, as might fairly be esteemed a variety of gneiss. (G.T. vol. iv. p. 403.)

§ 189. In the parish of Veryan in Cornwall, and in the neighbouring parishes, slates alternate with a limestone which is quarried; and which, when converted into lime, is used as cement and as a manure.

§ 190. The veins which contain copper or tin, or both, run east and west in Cornwall, and pass through both granite and clay-slate. Those containing silver, lead, cobalt, or antimony, run north and south, with little exception; and are, I believe, always in clay-slate.

§ 191. In cutting a tunnel for the Tavistock canal between the Tamar and the Tavy, in Devonshire, six elvan courses or channels were passed through. Three of them consisted of chlorite and quartz, or of granular and crystalline quartz; the substance of the other three is termed by the miner *grouan*, which is described as being a clay porphyry. These courses vary from 6 to 26 fathoms in thickness, are nearly parallel, and dip through the clay-slate (killas of the miner), of which the hill is composed, beneath the surface, at a considerable underlie, towards the north. On the surface, their direction is of course, nearly east and west. These beds are all intersected by some of the many tin and copper veins discovered in driving the tunnel, which is 1270 fathoms long, as is always the case with beds of the same description in Cornwall. (G. T. vol. iv. p. 152.)

At Torr Point in Devonshire, and in some other places in the west of England, clay-slate is said to include beds of greenstone. (§ 181.)

§ 192. The prevailing rocks of North Wales are slates of various descriptions: but scarcely any part of the principality has yet received that attention which it merits. Its mountain ranges consist in great measure of trap rocks (§ 182), with which slates are associated, and even in some places interstratified.

Clay-slate occurs in Shropshire as the supporting rock of the trap formation of that county. (§ 178.) It crops out to-day in the streets of Church Stretton. (G. T. vol. 1. p. 212.)

GNEISS.

§ 193. This rock has been noticed in Cornwall reposing on, or intermingled with the granite of that country, and will hereafter be mentioned (§ 207) as reposing on granite, on the northern side of the Malvern hills; but its characters are not very determinate. The clay-slate, on which rests the newer formation of granite of Cligga point in Cornwall, has been described (§ 201,) as being so intermingled with quartz and felspar, as that it may fairly be esteemed a variety of gneiss.

MICA-SLATE.

§ 194. Mica-slate is, like the preceding rock, of extremely rare occurrence in England. I am not aware of its having been noticed except by Dr. Berger, who describes it as forming the cliffs at the Lizard point in Cornwall, which extend into the sea, forming dangerous reefs and sunken rocks. That of the most southern point of the Lizard has a very brilliant lustre, is of a fawn colour, includes veins of quartz, and is evidently stratified. No garnets were observable in it. (G. T. vol. i. p. 129.)

GRANITE.

§ 195. The principal tract of Granite is to be found in the west of England. It there forms the central part of a *mountain-chain*, which, like all other ranges of primitive mountains, is in the direction of north-east and south-west; extending about 120 miles from near the center of Devonshire on the east, to the extremity of Cornwall on the west, and presenting a regularity in composition rarely to be observed in great chains. (G.T. vol. i.) The highest points of this range consist of granite; of which, the summit of the hill called Brown Willy, which is near Bodmin, and is about the center of the chain, is the most elevated point, being 1358 feet above the level of the sea. Towards the west, this chain slopes gradually, terminating at the extremity of Cornwall in a narrow tongue of land which is chiefly of granite; but on the east, its terminations are rather abrupt. We shall readily conceive that the granite tract of Devonshire and Cornwall is of great extent, when we reflect that the *mountain-plain* of Dartmoor alone, has a surface of 80,000 acres, or nearly 350 square miles. (G. T. vol. i.)

§ 196. According to the Wernerian school, there are two or three formations of granite. That of Cornwall, not being large-grained, is not commonly esteemed to be of the oldest formation. But this rock has not yet received that attentive examination which it merits, both from its extent and from the riches which are daily procured from its numerous veins,* and which appear to be inexhaustible.

§ 197. The granite of this tract, especially in its central and western parts, is subject to decomposition, as is evident, not only on the common surface of the country, but also by the many vast and rude blocks † of which the edges are rounded by that process, and the whole mass reduced to the most extraordinary and fantastic shape. That this effect is to be ascribed to that cause, and that it is not attributable to attrition, is demonstrated by the cavities visible in many masses, evidently still in situ, and in the bottoms of which the ruin occasioned by atmospherical action still remains. To decomposition also is attributed the existence of a tract of loose white earth, some miles in extent, which is quarried as a porcelain earth. It is not far from St. Stephen's, on the southern side of the granite range. The principal quarry is 830 feet above the level of the sea. It is a decomposed granite, the felspar of which forms two-thirds of the mass, in which crystals of quartz and scales of mica are imbedded, together with crystals of a compact earthy felspar. It is chiefly used in the porcelain manufactories of Worcester.

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* Some account of the metalliferous veins of Cornwall, and of those which traverse them, was given in my 'Outline of Mineralogy and Geology," &c. and still more at large in a communication to the Geological Society, which is printed in the second volume of its Transactions. The latter is now annexed to this volume.

† On this subject there is a communication in the Second Volume of the Transactions of the Geological Society, by Dr. MacCulloch. Amongst the remarkable rocks therein noticed, is the celebrated 'Logging Stone,' which, although it be 17 feet long, 32½ feet in circumference, and 65 tons in weight, may be moved by the force of a very few pounds, so as to maintain a visible vibration. Even the wind blowing on its western exposed surface, produces this effect in a very sensible degree.

§ 198. The conical hill called St. Michael's Mount, situated about a quarter of a mile south of Marazion, in Cornwall, is deserving of notice. It is surrounded by the sea at high water. It is chiefly of granite, which appears to have been split into immense irregular masses; on its southern side it is very precipitous. On its northern and western sides reposes argillaceous schistus, or according to Dr. Berger, greywacké, which does not rise far above the sea. In the granite, are veins containing crystallized tin, mica, quartz, small topazes, and crystals of apatite: the pinite is said also to have been discovered there. On the summit of the mount is a Gothic castle, one of the seats of Sir John St. Aubyn, which, being situate in a bay, commands a scene as delightful as the eye can contemplate.

§ 199. Besides the granite, strictly so called, of Cornwall, there are other rocks connected with it which may be termed granitic. The lower part of a hill, 100 feet high, near Ivy-Bridge, is composed of greywacké (argillaceous schistus ?) which is covered by a porphyritic granite, consisting of brick-red felspar confusedly crystallized, in which are imbedded crystals of vitreous quartz, hornblende, and tender steatite of a yellow colour. (G. T. vol. i. p. 118).

§ 200. No satisfactory observations have hitherto been made public, on the veins which are found in rocks superincumbent on the granite of Cornwall, and which, from the nature of the substances with which they are filled, have been termed granite veins. Meantime theory has been busy; but the student is advised to beware of giving, upon slight grounds, or even upon eminent authority, his assent to any theory now existing respecting their formation. Neither the nature nor circumstances of these veins is well understood: indeed their investigation is one of the points which is as difficult as any connected with the science; and it is the more essential that a decision of opinion respecting their origin, should be founded on a thorough investigation of the facts relating to them, which have not been adequately explored, since upon this decision depends, almost necessarily, the adoption of one or other of the two prevailing theories relative to the origin of the older rocks as they are commonly termed.*

§ 201. The newer granite formation of the Wernerian school is found in Cornwall, *resting on killas or clay-slate.* It is small-grained, the felspar is sometimes earthy, occasionally flesh-coloured; it contains but little mica, and encloses imbedded crystals of flesh-coloured felspar. The latter circumstance sometimes occasions the designation of *porhyritic granite.* A rock of this description, but varying frequently in the proportion of its ingredients, and consequently in its appearance, constitutes Cligga point, a considerable headland in Cornwall, five miles east of St. Agnes; and the clay-slate dips beneath it at an angle of at least 80 degrees from the horizon. The granite has been much worked for tin, which is disseminated through its mass in veins apparently contemporaneous. The clay-slate on which it reposes, occasionally presents singular curvatures. (G.T. vol. iv. p. 403). The granite of several parts of Cornwall, contains tin interspersed through it in a crystallized state.

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* See 'Outlines of Mineralogy and Geology,' 3d Edition, p. 201. We may shortly expect some matter-of-fact information on this very intricate subject, in the first volume of the Transactions of the Geological Society of Cornwall.

§ 202. In reviewing the two or three preceding pages, it will be observed that our knowledge of this formation, constituting a large part of the most important and most interesting of our mineral districts, conveys but little information respecting it. That our knowledge is thus scanty, is in part to be attributed to the too prevalent anxiety of viewing and describing geologically, large tracts of country, in which only the general features can be observed, in preference to confining the attention to smaller districts, which would allow of that minute investigation which may be termed mineralogical, and which is so essential to our proper knowledge of all rocks, more especially of those compound masses which are termed primitive.

§ 203. To what has preceded, it may be added that the granite of Cornwall is believed not to be *stratified*; it has not therefore been observed interstratified with any other rock; for the instance already cited (§ 199) of a *granitic* rock reposing on clay-slate, is not to be considered an instance in which true granite is so found, since the substances it includes are foreign to that rock. It is certain that in some of the mines of Cornwall, as in Tin Croft for instance, which is situated at the foot of a granite hill called Carnbrae, the miner sunk alternately through clay-slate, which forms the surface of the mine, and granite: but this circumstance is believed to have been owing to the casual protrusions of the latter rock, having caused cavities on the sides of the mass, which were subsequently filled by clay-slate.

§ 204. The rock commonly reposing on the granite of Cornwall is the *killas* of the miner, the *clay-slate* of geologists. It seems essential to apprize the student that in the general survey of the county by Dr. Berger, to be found in the first volume of the Transactions of the Geological Society, the rock lying on the granite is termed greywacké; an appropriation of the term which is not allowed by even the most strenuous advocates of the Wernerian nomenclature. It must however be added, that although the rock flanking the great granite chain of Devon and Cornwall, is, generally speaking, clay-slate, it is occasionally accompanied by greywacké (§ 165), though not to any considerable extent.

§ 205. This rock appears in several other parts of England, though, in comparison with the tract of which we have been treating, only in small patches.

§ 206. It occurs in small quantity and *in situ*, near the foot of a hill in the grounds of Westercombe, a few miles north-east of Taunton in *Somersetshire*, where there is a small quarry: the inhabitants of the neighbouring country call it *Pottle-stone*. It is small-grained, and consists of flesh-coloured felspar, green mica, and a small quantity of quartz. A mass of it appears in the form of a wall a few feet above the ground, and near it are visible many strata of the slates common to the greywacké formation; on the south-easternmost borders of which, the granite appears. Within a few yards of it, the inclination of the strata of slates is about 35 degrees, but nearer to it, the angle increases to 63 degrees. The granite is much finer grained near its junction with the slate, than in other parts, and at the contact there is an indistinct blending of the two, which has somewhat the appearance of fragments of the slate united by a granitic cement. The slate, in some places near its junction with the granite, takes the form of a greenish compact stone, resembling some varieties of hornstone; and is used in the neighbourhood as a whetstone. (G. T. vol. iii. p. 348.)

§ 207. Granite is again seen in the *Malvern hills*, which are about 9 miles in length, 1444 feet high, and run north and south near the borders of Herefordshire and Worcestershire. The granite of these hills is unstratified, and is so greatly decomposed as scarcely to be recognized. It is in that state which the quarry-men term rotten. It does not present the same crystalline appearance as the granite of Alpine countries. The felspar, in the more compact and best defined specimens, is usually red. On the western side, the granite is covered by stratified rocks, such as limestone, and an argillaceous rock, both of which enclose such organic remains as occur only in the oldest of the secondary rocks. On the eastern side, it is associated with sienite, and some varieties of trap rock. Gneiss reposes on its northern side. (G. T. vol. i. p. 317.)

§ 208. A few miles north of Leicester, near the center of England, granite rises, forming a part of the small elevation called *Mount Sorrel*, where it is associated with rocks of the trap formation, and with schistose rocks of various descriptions.

§ 209. At *Shap*, a few miles south-west of Penrith in Cumberland, it is found forming a ridge of no considerable magnitude, about 1200 feet above the level of the sea. I am not aware that the granite of the two latter tracts has been thoroughly examined, and I forbear to give such an account of it as hand specimens alone would furnish.

§ 210. It likewise occurs in the north of England, a few miles north-east of Appleby in Westmoreland, at the foot of *Dufton Pike*, on its western side, where it is entirely surrounded by greenstone. It is there quarried for field walls, and the opening is 45 feet broad. This granite consists of a bright salmon-coloured felspar, silvery mica, and a few small specks of quartz.* It also occurs two fields further west. Granite is likewise found a mile south of Dufton Pike, in a streamlet that runs to the village of Dufton; it resembles that of the hills on the south-west of Shap, and contains large flesh-coloured crystals of felspar. In a field adjoining, and on both sides of the water-course, lie large blocks composed entirely of dark mica, which are half buried in the soil, and appear to have been derived from a subjacent rock of mica connected with the granite. (G. T. vol. iv. p. 110.)

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* This granite much resembles that which is found at a place called Demming or Red Crag, at the highest point of the road between Shap and Kendal; and which, being only 30 feet wide, and lying between two walls of coarse slate, has been imagined to be a dyke (or vein). (G. T. vol. iv. p. 110.)

§ 211. Granite is found in the *Isle of Man*, but not of the oldest formation, in the opinion of Dr. Berger, whose communication on the geology of that isle may be consulted in the 2nd volume of the Transactions of the Geological Society; and he thinks that some doubts may be entertained whether, in the places in which it occurs, it does not lie in beds, rather than form the universal foundation of the isle. Another primitive rock, clay-slate, occurs there also, but not of the oldest kind. Of transition rocks, several varieties appear, but they do not contain organic remains. Flœtz limestone is also found there, accompanied by magnesian limestone. On the limestone lies an amygdaloid, consisting of wacké of an earthy texture, enclosing nodules of calcareous spar and iron pyrites. A conglomerate sandstone is also found, which in some places overlies the limestone.

§ 212. Granite has not yet been discovered in any of the great mountain chains of Wales, nor indeed in any part of the principality, excepting a small spot near the middle of the Isle of Anglesea.

ON THE

VEINS OF CORNWALL.

Some account of the Veins of Cornwall is given in my 'Outlines of Mineralogy and Geology,' &c. but of so general a nature, that I am induced to add to the foregoing pages, a more particular description of them, forming a communication which I made to the Geological Society, and which is inserted in the second volume of its Transactions. It contains accounts of several kinds of veins, and some geological facts, which, I believe, have not been made public in any other form; and as the whole subject is in every point of view of great importance, it will, I trust, be found interesting by the student.

A Visit to the county of Cornwall in the year 1800, the inducements to which were the objects of mining and mineralogical inquiry, afforded me many opportunities of conversing with practical miners. The subject was new to me; and it was with considerable pleasure that I listened to the many striking and interesting facts detailed by men ever ready to communicate the information they possess, and whose minds, as repeated visits to the county have since confirmed to be their characteristic, are habitually disposed to industrious ingenuity.

It may well be supposed that the foremost of these subjects was the nature and peculiarities of veins, or as they are technically termed, loads, or courses.* Having learned that the run, or direction of the regular metalliferous veins is about east and west, and that in some districts, the same vein is known actually to pass through several mines, it occured to me, as being within possibility, that at least some veins might extend the whole length of the county; and that if the situations of such mines as were then working, or had lately been worked, were accurately described on a map, it might throw some light on the idea. With this view therefore, after visiting many of the mines, particularly those of the mining district of which Redruth may be said to be the center, that object was accomplished by the assistance of some friends. The result by no means confirmed the idea in which it originated: for although it evinced that in the year 1800 there were about 120 mines in the county, either then working, or which had lately been worked, few of the east and west or metalliferous veins, from causes that will be explained in the following pages, have been explored, or even satisfactorily traced more than two or three miles. The map was however preserved merely with a view to private gratification; but several gentlemen, whose zeal for geological inquiry induced them to consider this attempt to shew the localities of mines as in some degree worthy of attention, urged my offering it to the notice of the Geological Society, accompanied by a memoir on the subject of the Veins of Cornwall.

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* I have been at some pains to discover the original meaning of the term *lode*, or *load*, as the technical appellation of the east and west, or metalliferous veins of Cornwall. Borlase in his natural history of the county treats at page 146 of the *Fissure*, and the next chapter begins thus: 'From the Fissures let us proceed to that which they contain, whatever fills them, we call a lead;' making a distinction between the fissure or vein and the substances it contains. He says in the same chapter 'where the load is barren, it may serve to *lead* us to what is rich;' and in a note, concludes the term *lode* to be an old Anglo-Saxon word, meaning *lead*; thus *load*-stone, meaning *leading*-stone,' and refers to Lye's Junius *ad verbum*. Without going so far back for an authority which nevertheless may be correct, I am induced to believe the term *lode*, though thus spelt by Borlase and Price, originally meant the burthen or *load* of the metalliferous vein. Carew, whose 'survey' was published almost a century ago, not only so spells it, but at p. 8, in speaking of the effects of the flood on the rocks of the county, says it carried away so much of the '*load* as was contained therein.' Besides it is to he noticed, that the north and south veins, which are not metalliferous, are uniformly termed *courses*, making a clear technical distinction between unproductive and metalliferous veins.

The map not being of course adapted to the present state of the mines, nor even sufficiently exact in regard to their several localities at the time at which it was compiled, to meet the public eye, its publication is laid aside for the present, not however without expectation of its being given in some future volume of the Transactions, in the most accurate and satisfactory manner.

But the ascertaining of the local and relative situations of mines, though of unquestionable interest to the geologist, can only be regarded as a link in the chain of inquiry. In order to render its value complete, it should be accompanied by a memoir, or rather a comprehensive history of each mine and of its connexion with those immediately contiguous to it on the same veins. But this could only be attained by years of unceasing and laborious inquiry on the spot. In the counting-houses of the most successful mines, the only information ever committed to paper in regard to the workings of the veins, are the expenditure and income, together with a section of the vein from which the profit is reaped, without a single notice in regard to the tract of country through which it passes. Of the generality of unsuccessful mines, which form by far the greater proportion, all that is registered is the loss or expenditure; other information can only be obtained by a recourse to personal inquiries of the conductors or captains.

The following pages are principally intended to exhibit an outline of general facts relative to the veins of Cornwall, arranged under separate heads. In drawing up this sketch, such advantage has been taken of what has already been published on the subject as seemed consistent with the present object, carefully rejecting every thing doubtful, or hypothetical, and having in constant view the advantage of corroborating every assertion, to the extent of my limited information, by a recourse to the peculiar circumstances of individual veins or mines. Though thus limited in its object and extent, it will I trust be found both consistent with its intention and accurate in its detail; nor will its service be trifling if, upon a subject so interesting, and on which little is known, it should be the means of inducing some of the numerous and well-informed men, who are immediately concerned in mines, to gratify the increasing interest which is felt on geological subjects, by giving to the world occasional details of the many curious facts that almost daily occur in practical mining.

Almost every mine of any considerable depth or extent, is deserving of the notice of the geologist, because each has its peculiarities:—for when two or more mines are on the same vein or veins, there is frequently but little else that is common to each; and even in the same mine, situated beneath a few superficial acres, there is often a strange variety in the dimension, contents, and direction of its veins, and in the country* through which these run.

Direction and Length of Veins.

It has already been remarked that the regular or metalliferous veins generally take the direction of about east and west; there are others both in the same and in different directions, most of which are very rarely found to produce any metallic substance; the nature and peculiarities of which will be noticed hereafter. The regular veins are almost uniformly of considerable length; some are known to extend two or three miles, having several mines on their run; and though the idea of their extending the whole length of the county may be judged to be hypothetical, it ought to be noticed that the most experienced miner never satisfactorily witnessed the termination of a vein either on the east or west. Many circumstances of disaster, and more particularly that of poverty, occur to prevent their extent from being known; but that there are instances of their appearing not to exceed a few fathoms in length, as in the Herland mine. In reality however the veins of that mine did not terminate abruptly, but continued both east and west, to an unknown extent, in strings so very small, as to be only just perceptible, and therefore not worth the attention of the miner, whose experience induces him to believe that when a vein diverges in metalliferous strings, however small, they would, if pursued, be found ultimately to increase in size, or to converge again, or to diverge to other veins, which are generally found to be, as it were, increased in size and value thereby. The east and west veins are sometimes found diverging from the straight line, and even when apparently unaccompanied by any circumstance that might be assumed as the cause, but they generally return and resume their customary direction. In Huel Fanny, I think, the vein suddenly took a course to the south-east, in a few fathoms it was found to alter its course again, nearer east; afterwards it ran about east, and then elbowing again, it resumed its usual direction, nearly if not quite in a straight line. But circumstances of this kind are by no means common.

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* I have used the word *Country* in the sense in which it is employed by the miner, and shall hereafter so use it, conceiving it to be well adapted, if not better than any other I have been able to find, to convey the intended idea. If a miner be driving an adit north and south, or in any other direction than that of the Load, he says he is "driving through the country."

Underlie of Veins.

With the exception of those alluvial deposites of tin, found in vallies and low grounds in many parts of the county, and in the working of which the tin is separated from its accompanying earthy substances by means of passing a stream of water over it, whence they have been called *stream works*, neither copper nor tin is found in Cornwall in layers or beds. The veins, in which only they are found, have a downward direction, not perfectly perpendicular to the horizon, but inclining more or less to the north or south; this inclination is called the *underlie of the load*, which in some veins does not exceed a few inches in a fathom from the perpendicular, but in others is a fathom in a fathom, or even more.

When two metalliferous veins underlie in opposite directions, that is, one north and the other south, and meet underground, the result is not always favourable to the miner; for even though they might have been rich when separate, they generally are found to be poor at and after their junction. But when two loads underlie in the same direction, and one of them quicker than the other, it is generally found that when the latter overtakes the former, they seem mutually to enrich each other.

Veins are not very frequently found to separate in the downward direction, so as to make branches forming distinct veins, having an opposite underlie. Instances of this however occurred in Tin Croft Mine.

Depth of Veins.

Not an instance, I believe, has occurred of a vein having been cut out in depth. When the working of a mine is relinquished, it is mostly either on account of its poverty, or the expense of sinking to a greater depth, being to a larger amount than the product. The mine called Crenver and Oatfield is 200 fathoms deep; Cook's Kitchen is 210; and Dolcoath 228 fathoms; these are the deepest mines in the county now at work.

Width of Veins.

The east and west, or metalliferous veins, are generally from one to three feet in width, but vary to 30 feet. In the old workings of Relistian mine for tin, there are chasms both open to day* and underground, full 30 feet wide. A vein from one to three feet in width is preferred, because, though many instances of the contrary have occurred, it is found that the product is generally as good as in wider veins, on account of there being, for the most part, less admixture of foreign substances with the ore.

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* Ore is said to be dicovered near the *day*, when it lies near the surface.

A vein sometimes varies in width in the same mine very materially, and is often found to increase in that respect in going down. One of the loads in Huel Alfred† varies from 9 to 24 feet: there is a peculiarity in its direction which is noticed in speaking of that description of irregular veins called Contres. As opposed however to the width of that vein, those of Herland and Drannack and Prince George mines, which are separated from Huel Alfred only by a brook and a cross vein, may be cited. There, instead of continuous veins of a somewhat irregular width, they are remarkably small, most of them varying only from two to six inches in the widest part, which was about the middle, and going away east and west in mere strings. A tin vein in Whealan Coates mine, not three inches wide was very rich, and found to be worth working.

If in working on the course of a vein, or in sinking through the load, the country is found to assume a greater hardness in a very considerable degree, the vein generally becomes narrower.

Denominations of Metalliferous Veins.

The substances which form the contents of the metalliferous veins differ very materially; nor are veins distinguished simply by the name of the ore for which they are wrought, as a Copper load, or a Tin load; but they have obtained various appellations, according to the nature of the substances found to predominate in them. For as the greater proportion of the contents of most of them, is neither the ore of copper nor that of tin, the miner in speaking of them, gives them the appellation which is technically descriptive of the vein-stones:—as a gossany, sparry, mundicky, peachy, flucany, scovan, caply, pryany, black jack, and a grouany load.

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† *Huel* signifies a Mine, according to the Cornish-English Vocabulary of Borlase. It is commonly, though erroneously spelt, Wheal.

Gossan is a friable ferruginous substance, consisting generally of clay, or of some siliceous matter of a loose texture, coated or tinged with iron, in various proportions, arising probably from the decomposition of pyrites; it varies in colour, from pale yellow to deep red, sometimes inclining to black. A gossany lode is more common than any other, and most promising both for tin and copper. Gossan has been plentifully found at small depths in many mines that produced considerable quantities of one or the other metals, both beneath as well as mingled with it; as of tin in Huel Sparnon and Pednandrae, and of copper in Huel Gorland, and in East and West Huel Virgin.

When the load or contents of a vein are termed *sparry*, this does not imply that it is of solid spar or quartz, but that quartz predominates. A vein in which this substance is considerably compact is very unpromising; and if at the same time the vein becomes narrower as it descends, it is generally relinquished as a hopeless undertaking; which was the case in Huel Gorland, as noticed in my memoir on the red oxide of copper.* A vein abounding in fluate of lime is often termed a *sparry* load. Quartz is sometimes called hard spar by the Cornish miner, and fluate of lime sugary spar.

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* Geological Transactions, vol. i.

If iron pyrites abound, the load is said to be *mundicky*, and when this occurs at a shallow level, it is not always unpromising: even if it continue in depth, and be somewhat compact, particularly if mingled with portions of yellow copper ore, there are many instances of such veins proving rich beneath. No distinction is made by the miner between iron pyrites and arsenical pyrites. The latter is however rarely very abundant.

A vein that contains a great proportion of chlorite is termed a *peachy* load: it promises for tin rather than copper, which is rarely accompanied by chlorite. Tin was found in it, in Pednandrae, Polgooth, Relistian, Huel Unity, and in many other mines. I have specimens of the yellow copper ore in chlorite from Relistian and from the Wherry mines, the workings of the latter of which were under the sea in Mounts' Bay.

A vein is said to be *flucany* when either one or both its sides, or walls, are lined with a whitish or bluish clayey substance, or when this substance is interspersed through the vein itself. Flucan in some few instances has abounded so greatly, that it has been difficult to prevent its running in upon the miner in working the mine. This was the case in the early working of the productive copper mine called Huel Alfred, as is noticed in the annexed description of some of its veins.

When tin ore is intimately mingled with quartz and chlorite, the vein is termed a *scovan load*, which is of a dark brown or of a greenish hue, but not very hard, or compact. A load of this description rarely exceeds 12 or 14 inches in width, but it sometimes occurs in a vein the contents of which are not solid, thence by the miners termed a *sucked stone*. A load so circumstanced is often several feet wide.

A vein is termed a *caply load* when consisting of a hard, compact and unpromising substance, which seems principally to be quartz intermixt with minute portions of chlorite, giving a greenish, or brownish green tinge to the mass. Tin is often found in it, copper rarely. But if a branch of copper ore, or a gossan be found to take its course down the vein, it commonly makes a durable copper mine.

A vein is said to be a *pryany load*, when the tin or copper ore does not occur in a compact state, but when the stones containing either of them are found mixed loosely with other substances, such as gossan or flucan. *Pry* in the Cornish language signifies clay.

A vein that abounds in blende is called a *black jack load*, which is generally unpromising for tin, but is considered a good omen for copper. It is rarely found that blende continues to any considerable depth. It is also called mock-lead by miners.

Grouan * is the common technical term for granite, so that when a vein abounds in that substance, either in masses or blocks, or in a decomposed state, it is called a *grouany load*, which is rarely found unless in a granite country. Grouan is more promising for tin than for copper; though veins containing the latter have often of late been found in the granitic districts of Cornwall, of which the western part of West Huel Virgin, Carharack, and Huel Damsel, all rich copper mines, are instances.

It must be remarked that veins generally take their names from the substances which abound but a little way beneath the surface. But, the circumstances of veins change so often, and their contents frequently participate so largely of the nature of the country they traverse, that the same appellation will not often hold for them in depth. A satisfactory trial of their nature and value can rarely be made, without sinking 30, 40, or even 60 fathoms below the surface, and driving, at various depths, east and west on the "course of the load."

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* *Grouan* signifies gravel, in the Cornish language, *Borlase.*— It seems therefore probable that Grouan, correctly speaking, is decomposed granite.

Symptoms in Veins.

In the whole range of the employments of man, there is not perhaps another in which experience and ingenuity are more often and completely baffled than in mining. Not unfrequently the appearances in a vein, considered to be of the most promising kind, lead on the most experienced miners during the lapse of many years, only to ultimate and immense loss; while on the other hand, from the product of veins, which by men of not less experience have been declared to promise no advantage, large profits have been reaped. The great copper mine called North Downs, in the working of which no less a sum than £90,000 was lost, may be considered as an instance of the first, and Huel Alfred, from which a greater sum has been gained, is an instance of the second. There is scarcely one symptom on which the miner most relies that has not occasionally deceived him. It may be curious however to add some of the symptoms in favour of which the miner is greatly prejudiced. There is no one more favourable in his estimation than a gossany load. I remember that of North Towan Mine was of this description, and of so great promise, that several of the most experienced practical miners did not hesitate to declare it superior, in that respect, to any other they had seen; and that, if compelled to venture all they possessed, in the working of any one vein, it should be that of North Towan; but, after much time and expense had been bestowed in trying it, it was found to be very poor, and was therefore abandoned.

The early discovery of iron pyrites and portions of yellow copper ore mingled with a large quantity of blende is considered a favorable omen for copper. Blende, as has already been noted, is by the miner called Black Jack; and ‘Black Jack,’ he says, ‘rides a proud horse,’ a phrase become proverbial, from blende being often found to lie above, in a vein rich in copper beneath. Vast quantities of it were found above the ore in the productive copper mine Huel Towan, as well as in that called North Bennar. The early discovery of lead is also considered a good symptom; very many tons of it were sold from Huel Alfred in the state of sulphuret and carbonate. Iron pyrites at a small depth is also considered a favorable symptom for copper in depth, as was proved among many others, in the rich mines of Crenver and Huel Virgin; but when it proves solid, it has often discouraged the miner and induced him to abandon the vein. The cutting of a ‘good course of water’ is esteemed no unfavourable circumstance, epecially if it be warm, and it is not uncommon to find water issuing from one part of a vein of a temperature sensibly higher than that in other parts of it. So greatly indeed does water abound in rich veins, that on extensive and deep mines are mostly seen two, three, and even four steam-engines, for the purpose of drawing it, the cylinders of which are from 30 to 66 inches in diameter. If a vein be particularly rich, it is considered to omen well for the parts of other veins immediately north and south of its riches; to express which the phrase of “ore against ore” has been adopted.

It would scarcely be correct to say that the early discovery of tin in a vein, is a good promise for copper in depth; but it is certainly true that tin is frequently, if not mostly, found at a small depth in veins, afterwards proving rich in copper. Among many other instances of this that might be quoted, are the two deep and extensive copper mines called Huel Unity and Cook's Kitchen, both of which were, I believe, worked for tin at first, without any suspicion of their veins being rich in copper beneath it. In both the tin was soon exhausted; but it should be noticed as an uncommon circumstance, that in the latter mine, after working to the depth of 180 fathoms, first through tin and afterwards through copper, tin was found again, and has continued down to the present depth of the mine, which is about 210 fathoms from the surface. It ought however to be noticed that some parts of that portion of the load which principally contained copper ore, had been left, on the presumption of their not yielding ore of any sort; in the phrase of the miner they were considered as *deads*. Some of these have since beeen found to produce tin, which may consequently be said to have prevailed more or less from the surface to the bottom of the present working. A considerable proportion, if not the chief part of the copper ore of this mine, was the sulphuret.

Among the favorable symptoms to which the miner is attached there is still another, which ought not to be forgotten. There are some among them credulous enough to believe that they hear, while employed under ground, another pick at work, which is immediately referred to the agency of an evil spirit, or what they term a piskey, or small man. This is esteemed an omen of the most favorable kind, and which induces the full belief of having nearly arrived at the desired object, the discovery of 'a good course of ore.' It seems as though the sound which the miner hears, may reasonably be accounted for by presuming him to be at work in the immediate neighbourhood of a cavity, or as he terms it, a voog, which returns the sound of the stroke of his own pick.

Discovery of Veins.

The discovery of metalliferous veins is effected in various ways. Amongst the foremost of these, Pryce places that of the Virgula Divinatoria; but, after a long account of the mode of cutting, tying and using the rod, interspersed with observations on the great difference existing in the discriminating faculties of constitutions and persons in its use, altogether rejects it, because 'Cornwall is so plentifully stored with tin and copper lodes, that some accident every week discovers to us a fresh vein,' and because 'a grain of metal attracts the rod as strongly as a pound,' for which reason 'it has been found to dip equally to a poor as to a rich lode.' These, it must be acknowledged, are substantial reasons for the neglect and disuse into which the rod has fallen. There are not however wanting even now, in Cornwall, some who maintain the value of it. I am acquainted with one person who has repeatedly declared to me that, while using it in his own shop in the town of Redruth, he discovered a vein which has since formed a part of the workings of Pednandrae mine for tin. On the other hand, an intimate friend, well conversant with mining concerns, was present in Somersetshire with some noblemen and gentlemen, the proprietors of land in that county, anxious for the discovery and working of veins supposed to run through their estates, when a person who professed the skilful use of the divining rod assured them he could effect their wish. During one of his attempts, my friend, as though by accident, took his station immediately facing the professor of the rod, who advanced with the rod dipping as he declared to the run of a vein; my friend retreated, and in his retreat made a circuit, which as he had in some degree caught the attention of the person holding the rod, was followed by him; and the pegs that were inserted in the places his feet had touched proved the circuit he had made. If a vein actually ran in that direction, it is certainly wholly different from that of any known vein. It is almost needless to add, that the discovery of the supposed veins as indicated by the means of the divining rod, was not attempted.

The ancient mode of *shoding* for tin-veins, consisted in tracing certain stones, of which tin formed a proportion considerable enough to excite attention, and found at or a little below the surface, to the vein from which they had been accidentally detached, so as to have passed in a sort of succession down the side of a hill. Another mode of seeking tin veins is by sinking pits through the superincumbent earth down to the solid rock, and driving a trench from one to another, north and south, so as to meet with every vein in the track through which it passed. This method, which is also esteemed to be very old, is called *costeening*.

The former of these methods for the discovery of tin veins is now rarely resorted to; but the second, as well as another which differs not much from it, that of working drifts across the country from north to south, is sometimes practised. Many tracts of the mining part of Cornwall are however so amply stored with veins in the direction of east and west, that there is little occasion to employ either of the above mentioned modes of discovery. There are comparatively but few mines which are known to have within their boundary only a single vein; in some there are 5, 6, or even 7. As the driving of an adit home to a vein, is one of the first and most important tasks of the miner, he sometimes embraces the opportunity of so doing from a neighbouring valley along a cross course, or north and south vein, and for two reasons; the first, that the expense is less than if he were to drive through the solid country; the second, that he has at least a good chance of meeting with all the veins between the extremity of the adit and the vein to which he intends to drive it. Yet of this he is not altogether certain, for the east and west vein is sometimes so greatly disordered by the cross vein, as that it might wholly escape the notice of the miner; besides, cross veins often divide into branches, so that the miner runs the hazard of following the wrong branch, and thereby of missing altogether the metalliferous vein. But although the mode of discovering veins, by driving an adit along the run of a cross course is at once the cheapest and most expeditious method, it is not always practised, as the foresight of the experienced miner sometimes induces him rather to drive through the solid country than to hazard the chance of being obliged to draw the water of the country all around him, which he is aware the cross vein would prevent from troubling him on one side.

Accident often occasions the discovery of veins. That of the mine called Huel Maggot, or Velenoweth in the parish of Phillack, was first seen by workmen employed in digging a trench for the foundation of a garden wall in a valley. It there consisted of a rich gossan, which in the phrase of the miner was *very kindly*. On driving into the hill, a few fathoms on the 'course of the load,' it produced abundance of sulphat of lead in well defined crystals, sometimes accompanied by the sulphuret, and sometimes deposited on the gossan, and, a little deeper, copper ore in considerable quantity. Both were however soon exhausted, and the mine was abandoned. The run or course of an east and west vein may sometimes be traced on the surface, by loose fragments or portions of earthy or stony substances, having generally more or less of an ochreous tinge; but this, which is called the 'bryle of the load,' has rarely a regular separation from the country on each side of it. But in sinking a few fathoms below the surface, it assumes more determinate marks of being a fissure.

Contents of East and West or Metalliferous Veins.

The contents or load of the generality of veins, if at all attached to their sides, are for the most part easily separated. A dark ochreous crust occasionally covers one or both sides of the vein, technically called the *walls of the load*; and when these, or at least one of them, is regular and determinable, they are more encouraging to the miner than when rough and uneven. A thin coating of flucan is found on one, or occasionally on the other wall, or sometimes on both walls of a metalliferous vein; but it is said that this coating or vein of flucan is most commonly found on that which, in regard to the underlie of the vein, may be called the upper wall.

It has been already noticed, in speaking of the denominations of metalliferous veins, that there is a great diversity in their loads or contents, and that the same vein exhibits so little uniformity in that respect, at different depths, as to assume various characters. Near the surface the load consists for the most part of a sort of ochreous rubble, probably the debris of the neighbouring country; beneath which, though rarely nearer grass than 20 or 30 fathoms, are found some metalliferous indications. These, if gossan be the prevailing substance, consist of the ores of tin or copper. But iron pyrites, blende, fluate of lime, quartz, and sometimes chlorite, or flucan, frequently prevail for many fathoms, occasionally mixed with portions of the country through which the vein passes, though frequently with but slight traces either of tin or copper. A vein is sometimes found to consist of little else than a bed of hard and unpromising iron pyrites, which occasions its being abandoned; in others are found the ores of tin or copper, sometimes both, intermingled with some, or even most of the foregoing substances; but if they occur together, the copper for the most part prevails to such an amount, as that all traces of tin are lost in depth. In some veins however they continue to be found, even to a considerable depth, though not often much intermingled, but in separate bunches; this as has already been noted, was the case in Cook's Kitchen Mine; the neighbouring mine, Tin Croft, also furnished a somewhat similar instance, though not I believe in the same vein; but these must be considered as somewhat rare occurrences.

Tin is commonly found much nearer the susface than copper. When either is very near, especially if abundant, it is in the estimation of the miner an indication that it will not continue to a very considerable depth, of which Cornwall furnishes numerous instances. There is a tract of country situate about midway between Truro and Redruth on the north of the high road, in most of the mines of which, and amongst them the great mine called North Downs, the ore for the most part occurred near the surface, and was almost uniformly found to extend but to a small comparative depth.

Although there are veins in various parts of the country which have yielded copper in its pure state in considerable abundance, in masses interspersed through them, and but little intermingled with other substances, or even with the ores of copper, yet the most common state in which this metal is found is that called yellow copper ore. It is more continuous and lasting than any other. There are veins which yield only the grey sulphuret, but this rarely or never continues, being found only in bunches. It is sometimes mingled with the yellow ore. As a proof of the great difference in the value of the ores of veins, it may be noticed that there are many which seldom yield it of a greater price than £4 or £5 per ton. A few tons were lately sold from the United Mines at £100. The general average perhaps does not exceed about £7 10s. or £8 per ton.

In few metalliferous veins does the ore prove so continuous, as, after it has been taken away, to leave a large hollow vein. The intermediate spaces between the ore are mostly filled with what the miner terms *deads*, which consist of quartz, fluor, gossan, iron pyrites and other substances, as well as occasionally portions of the country through which the vein runs; but the walls of the vein are nevertheless generally determinable. The deads are not always a disadvantage to the miner, as they serve to keep apart the country on either side the vein; but for this purpose, when the vein has been left hollow by taking away a large body of ore, strong timbers are made use of; these are not however always found to be of strength sufficient to prevent the falling in of the cavity. An instance of this occurred in the copper mine called Huel Alfred, one of the veins of which was hollowed out for about 100 fathoms in depth, 80 fathoms in length at bottom, and 30 fathoms above, and varying in width from 9 to 24 feet. Notwithstanding great labour, skill and expense had been bestowed, and the most substantial timber employed in order to keep apart the wall of the vein, many thousands of tons came down in an instant; fortunately seventeen men, who had been working in the very place on which the whole fell, had left it half an hour before the accident. The whole has been supported, and they are now working beneath it.

It has sometimes happened that in a large vein, and where it is largest, the miner has suddenly arrived at a piece of dead ground in the middle of it, which in depth spreads wider, so as to occupy nearly the whole of the vein, leaving on each side only a small connecting string of ore. This has been known to extend many fathoms in length and depth, and from its being narrow above and widening below, it has obtained from the miner the name of *a horse.* The phrase on meeting with it is, 'the load has taken horse.'

The riches of a mine have in many instances proved the cause of great speculation, and consequent disappointment to those concerned in the mines immediately contiguous east and west, and on the same vein or veins.

This has been but too unfortunately verified in the instance of East Towan Mine, which joins Huel Towan on the east; in the latter, which has, during the last 10 or 12 years, from one large and unusually continuous bunch of yellow copper ore (the discovery of which was the result of a search of at least 30 years at a great expense) yielded a very large profit. There were 50 fathoms of good ore-ground in the vein at about 66 fathoms under the adit, which adit is 42 fathoms from the surface, or in the technical language of the miner, from grass. The bunch of copper ore continued to that depth from near the adit level, and as in length it extended east towards East Towan Mine, expectations were raised that the load, in passing through that mine, would prove equally rich. Great speculation and expense of course ensued; but in vain. For it was found that in several of the levels in Huel Towan, the ore ceased within a very few fathoms of East Towan Mine, and in some places as suddenly as if it had been cut away by a hatchet. This was not the effect of a cross vein, but purely one of those accidental circumstances to which copper loads are very liable. The ore of Huel Towan is of a remarkably bright yellow, and generally pretty compact, but not hard.

Adits.

When it has been determined to try a vein, one of the first objects of the miner is to bring home an adit to it. An adit is a water course, or rather an underground passage, about 6 feet high and 2½ wide, and is begun at the bottom of a neighbouring valley and driven up to the vein, for the purpose of draining it of water above their point of contact. In the event also of the mine having a steam engine upon it to raise the water from a still greater depth, it is not raised by the engine to the surface, but delivered into the adit. The general level of the mining-country east and west of Redruth is, according to Dr. Berger, from 350 to 450 feet above that of the sea, except where the granite overtops the schist, as in the instances of Carn-brae, Carn-math, and some few other hills, the summits of which are at a considerably greater elevation. This general level of the country is intersected by frequent vallies, which afford great advantages for the formation of adits, and consequently for the carrying away of the water from the mines. One adit frequently serves this purpose, for two, three, or more mines. Pryce, who published his work, entitled Mineralogia Cornubiensis, about 30 years ago, says p. 148, ‘ Though we seldom see an adit half a mile in length, there are two or three of three times that length, these are the longest that I know of.’ But since his time, one has been driven through a considerable tract of country at the lowest possible depth, as its mouth or extremity is nearly on a level with the water in one of the creeks of Falmouth harbour, into which it empties; and being below all other adits in that neighbourhood, it is called the deep adit. It does not run in one course, either direct or circuitous, the whole of its way; but taking into calculation its various branchings in and through the numerous mines (those of Gwennap) which it relieves of their water, it may be said to be about 24 miles in length.

Taking into consideration the purpose of an adit, it might be presumed that it is wrought on an inclined plane from the place at which it joins the vein to the extremity in the valley. This may perhaps be the case with some, but the practice is not uniform. By making them on an inclined plane, a freer current would be given to the water, yet much of their benefit would be lost, even although their declination were not to exceed one inch in a fathom. For, in supposing this plan to have been pursued in the driving of the deep adit above mentioned, which, from its extremity to North Downs mine, is about four miles or 3520 fathoms long, it will be obvious that if a declination of one inch in a fathom be allowed, the elevation of the adit at North Downs mine would be about 300 feet above its extremity; an elevation nearly if not quite equal to that of the surface of the mine. If therefore in the driving of an adit any allowance be made for the current of water it may be presumed that the interest of the miner will induce him to make it as small as possible.

Country.

Veins containing copper, as well as those containing tin, are found both in granite and in schist, though until within the last 50 years, it was esteemed in Cornwall a hopeless expectation to find a vein containing copper in the former of these rocks. Experience has however in many instances, in the parishes of Redruth and Gwennap, as well as in some others, proved that veins of copper ore are found in granite. In both of those parishes granite and schist have in some mines been found to alternate; this alternation has not, as I conceive arisen from their stratification, but from the casual unevenness of the first being supplied by a deposition of the second. It has, I believe, been but rarely noticed that the course of a vein has been along their junction; but some instances of this have certainly occurred; and I was informed by Capt. William Davey of Redruth, one of the most skilful and intelligent practical miners of the present day, and who was the principal manager of Huel Gorland mine, that for some fathoms both in length and depth, one wall of one of its veins was of granite and the other of schist; another instance occurred in Tin Croft mine.

The alternations in the country from schist to granite and back again to schist, are very frequent in some of the mining districts of Cornwall, so that it is impossible in a word to say in which some of the mines are situated, but I suspect this to be principally the case with those mines that are at the foot, or in the immediate neighbourhood of granite hills. I have not noticed any instances of the junction of these two substances in which the granite has not shewn a tendency to decomposition: it is sometimes separated from the schist by a slight ferruginous seam.

It will of course be understood that great variations in the texture and hardness both of granite and schist are observable. Of the former there seems every possible difference in hardness between the decomposed granite of Tol-Carn mine, which, as well as that of several others, it was impossible to keep apart without lining the adit or the level with boards close to each other, both above and on each side, and the compact and fine grained granite, of which quartz forms a principal ingredient, and which in hardness is almost equal to porphyry. Of the great difference in the hardness of schist, I shall notice one instance in Huel Alfred; in the sinking of two shafts in that mine, not much exceeding the distance of 50 fathoms from each other, the pay to the miner was in one instance £55 per fathom, but in the other only £5.

These frequent variations in the country through which the miner is under the necessity of passing in the usual course of his occupation in the sinking of shafts and driving of levels and adits, often prove the occasions of great hindrance and loss. There is a narrow channel of a remarkably fine grained substance consisting of compact felspar and chlorite, running in the direction of east and west, a little north-west of Redruth, which is so exceedingly hard as to have obtained the technical name of Ire-stone or Iron-stone. It was met with in driving an adit towards a mine, the Old Pool, I believe, and it has often been told me, that it was so remarkably compact in one place, as immediately to turn the point or edge of every tool, so that it was found impossible to drive a hole deep enough to employ the blast by gunpowder: the miner was compelled little by little to pick through that part of it, in doing which the seat-board was not once moved forward during the space of twelve months.

The schist of Cornwall varies much in colour as well as in hardness. It passes from lightish grey through the shades of slate colour to that inclining to a reddish hue, which is considered to be promising as to the occurrence of tin. But that which is esteemed the most kindly both for copper and tin, as well as the least expensive in the working, is of a light grey colour inclining to slate. This kind of schist is easily broken, and may be left without much support, and is therefore what the miner terms *feasible ground*, but it often passes in depth into a far more compact kind, of a dark colour, inclining to blue.

Cross, or North and South Veins.

It has already been noticed that there are veins in Cornwall, which as they are found almost uniformly to traverse the east and west, or metalliferous veins,* in the direction nearly of north and south, are technically termed *Cross Courses.* They rarely produce copper or tin, or any other metallic substance. They vary from half an inch to a few feet in width : the underlie of some is east, of others west; others again have no perceptible underlie, but are nearly perpendicular to the horizon.

In some tracts of the mining country they are of very frequent occurrence.

Cross Courses, or north and south veins, may be subdivided into, 1st, a Quartzose vein, to which the general term of *Cross Course* has been given—2nd, a vein containing a soft marly or clayey substance of a bluish or whitish appearance, called a *Flucan*; and 3d, a vein containing a substance of an ochreous and friable nature and of a yellow colour, called by the miner a *Cross Gossan.* Every cross course or cross gossan is however accompanied by a flucan. In speaking of these veins, the miner sometimes gives them their technical appellations, but he is more habitually disposed, whatever the substances of these veins may be, to call them by the familiar name of cross courses.

The principal advantage derived from the north and south veins is, that, when their substance is flucan, or even when a continuous vein of flucan, however thin, accompanies the quartz or gossan, they prevent the water of the neighbouring country from troubling a mine, and they are sometimes left to perform that useful office, as was the case between Huel Sparnon and East Huel Sparnon, near Redruth. But their disadvantages are numerous; for although the regular metalliferous veins are occasionally found to be but little or not at all disturbed by the passing of the substance of the cross vein through them, except by the mere division of the load, it more often happens that it is, as it were, broken into small strings or branches. By a careful examination of the nature and direction of these, the miner is indeed sometimes enabled to find pretty readily that part of the load which is on the other side of the cross vein, but he is often baffled. Instances have occurred in which the load has, as it were, been turned by the cross vein, so as to form what the miners term *an elbow*.

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* A rare exception (the only one I am acquainted with) has been found in the mine called Huel Alfred; a description of some of its veins is annexed.

Not only does the substance, whatever it may be, of the cross vein, almost uniformly pass through that of the metalliferous vein, but it is often found so to interrupt its course, as, in the phrase of the miner, to *heave* that part of the vein, east or west of it, a few inches, or even many fathoms north or south: and as the metalliferous vein is frequently found to be poor on one side of the cross vein, though rich on the other, its occurrence sometimes not only baffles the skill of the most experienced miners, but also causes much loss and vexation, as was the case in the mines called Tol Carn, Huel Jewel, and Huel Damsel.

Though the cross courses, or north and south veins, are rarely found to be metalliferous, or even to yield any of the ore of the east and west veins through which they past, a general exception was found to exist in those of the great tin mine near St. Austle, called Polgooth, in which, I believe, they universally produced tin. Two of the cross veins in Herland and Drannack mines yielded silver—one of them very sparingly, in the other it was accompanied by other metallic substances: the quantity of silver amounted in value to 8 or £9000. Pryce says[*] that cobalt has been found in veins of this description, that others have been worked for lead, and [†] that the direction of antimonial veins is mostly north and south, but that he had not known 'any producing that mineral of more than fourteen fathoms deep.' The mine called Huel Boys, which formerly produced the triple sulphuret, is now worked for antimony, which occurs in bunches of various dimensions in a vein, the direction of which is nearly north and south, and of about five feet in width. The antimony is accompanied by blende only, and is not now often found in a state of crystallization. The country through which the vein runs is schist.

Slide.

Veins, not of a metalliferous kind, but which contain gossan, or flucan, are sometimes found running north and south, and having an east or west underlie, which generally is very quick. Veins of this description are also found in the direction of the metalliferous or east and west veins, having an underlie north or south. But whether their direction be east or west, or north and south, and whatever their underlie, they are frequently the cause of much expense and vexation to the miner. When the underlie of this species of vein is in the same direction as that of the metalliferous vein, but quicker, so as to overtake it in depth, the latter is generally divided by the former, and, as it were, removed from its regular course. The load of the metalliferous vein is also sometimes altered in respect to its value, above or below its section, and the space between *a* and *b*, as it regards the load, is as it were lost.

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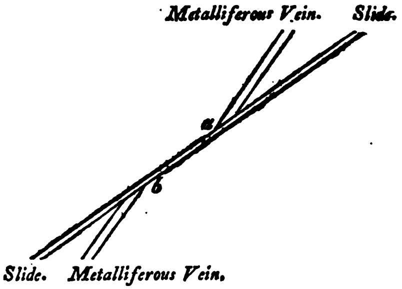
[*] Min. Cornub. p. 50. [‡] Ibid. p. 50.

North & South Section.



This kind of vein, from its direction, has obtained the name of *Slide*, and the phrase is, ‘ the load is cut out by a slide ;’ its flucan or gossan, generally traverses that of the north and south, as well as the east and west veins.

Heave.

But when the underlie of this species of vein is in opposition to that of the metalliferous vein, the effect of it is immediately the *reverse* of that of the slide, and is called the *heave*. Pryce has noticed a remarkable instance of this which occurred in the Goon Laz and the Pink tin mines, in the parish of St. Agnes. The tin load underlaid north, the gossan vein south. At 62 fathoms in depth, it separated the tin load, *heaving* the other part of it up 22 fathoms in perpendicular height, and 19 fathoms horizontally north. Another gossan vein afterwards cut the tin load, heaving it up also. The tin load then resumed its course, until another gossan vein separated it, again heaving it up.*

It will be understood that the effect of the heave is that of affording a greater portion of the tin load at a given depth from the surface, than would have been the case had the vein pursued its regular downward direction. But this is not always a compensation to the miner; for the vexation and expense accruing to him in searching for the tin vein, generally exceed any advantage to be gained by the heave. It was, I believe, principally the effect of a heave that baffled the skill and experience of the most eminent practical miners in Huel Peever; in which mine they were, during about 40 years, in search of the load, and which was at length discovered. Perhaps the history of that mine, and of the long and vexatious search, occasioned by the loss of the vein, would prove the most satisfactory evidence that can be obtained of the strange phenomena occasioned by the heave; and I have the satisfaction of knowing that it is the intention of a gentleman, who has nearly completed an account of it, to present it to the Geological Society.‡

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* See Plate 2d, of my 'Outlines of Mineralogy,' &c. exhibiting a Section of the Pink Mine; which also forms fig. 7. of plate 7. to the 2d vol. of Trans. of the Geological Society.

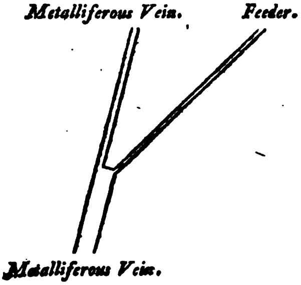
‡ It has since been printed in the 4th volume of the Geological Transactions.

In describing that effect produced by the interruption of one vein by another, called the heave, it ought to be noticed that a copper vein going down with a quicker underlie than a tin vein, always passes through it, and sometimes interrupts its regular course. And if the underlie of the copper vein be south, and that of the tin vein north, or vice versa, the copper vein continues its course, but interrupts that of the tin vein, heaving it out of its first direction; and although Pryce has merely given the appellation of 'Gossan' to those veins that heaved the tin veins, as just noticed, it seems to be probable that these 'Gossans' were veins containing copper, which is rendered the more so, as the term 'Gossan' is frequently given to a copper vein, merely from its being the prevailing substance. The heave of tin by a copper vein was, I believe, one of the remarkable and complicated disasters which befel the veins in Huel Peever.

Feeder.

A small *metalliferous vein or string* is sometimes found to take the same course as the east and west vein.

North & South Section.

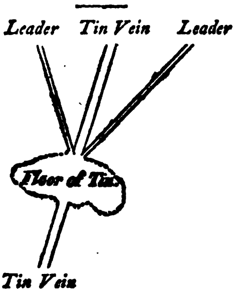


When its underlie is so much quicker than that of the latter, as to overtake it in going down, the metalliferous vein is generally found to increase in size, not merely in the proportion of the addition of the lesser vein, but very much more, so as to make a great body of ore, called by the miner a *gulph of ore* at their junction. This species of vein is therefore termed a *Feeder*.

Leader.

While working on the course of a load, small metalliferous branches or strings are occasionally observed to strike into the vein from the north or south, which, it seems probable, have before diverged from the same, or some neighbouring vein. It is not certain that copper veins are equally subject to this circumstance as are those of tin. In Polgooth and Carnmeal tin mines, their effect was the sudden enlargement of the load to what is termed a *floor of tin*, twelve feet or more in breadth, but without the determinate walls usually observable in regular veins.

North & South Section.



A floor of tin rarely continues for any considerable length or depth, and the load is generally soon found to resume its usual size and appearance. From the common effect of this kind of branch or string, it is generally known by the term *leader*.

The Contre.

There occurs still another species of vein, of which the course or direction is generally about north-east and south-west, and which therefore is oblique in respect to all other veins; from this circumstance I presume it to have obtained the name of *Contre* or *Caunter*. These veins are mostly, if not always, metalliferous: several instances have occurred of their being remarkably rich. An instance will be noticed in the annexed description of Huel Alfred mine, in which the contre was very productive of copper ore. A similar vein occurred in the Herland mine.

It may here be noticed, that in the former of those mines, the regular or east and west vein was disturbed by the contre, and for some distance totally disappeared on the west. In the latter, both the load of the regular vein and that of the contre were enlarged, and became more productive by uniting.

Elvan.

Elvan is one of the three grand distinctions made in regard to rocks by the Cornish miner. Whatever is not grouan (granite) or killas (schist), is of course with him, elvan. So that, in fact, it is extremely difficult to say what it is, or even what it is not, with the exception of granite and schist. The substance to which it is most commonly applied occurs frequently in Cornwall, not as forming tracts of country, but interposed betweeen the schist, in what is termed by the miner a channel. I know of no instance of its thus occurring in granite. The situation of these channels is not horizontal: they generally dip at various angles with the horizon, and in various directions. The colour of elvan is bluish-grey, or yellowish. It does not always disturb the contents of the metalliferous vein, which generally continues through it, though the load is mostly narrower than when in the schist; but it sometimes has the effect of dividing it into small branches.

In the preceding pages I have aimed at giving a mere general *outline of facts*, which, considering the imperfect state of geology, seems to be rendering better service to science than could be derived from a feeble attempt to raise upon their basis any theory explanatory of their occurrence. Nor indeed is the knowledge of insulated facts sufficient to authorize such an attempt on this important and difficult subject, comprehending operations on so grand a scale, of a date so remote, and throughout a country so greatly diversified. Before such an explanation can be satisfactorily accomplished, we have much to explore and to learn. The task seems to require a combination of talent and of information, which but rarely exists. But that a faithful detail of mining facts may contribute to assist the geologist in his inquiries, can no more be doubted, than that the science of mineralogy is absolutely essential to assist him in his researches.

It is to be regretted that the practical miner, in every part of England, is almost wholly ignorant of the principles and facts of mineralogy and geology. Even the conductors of the mines, termed captains, are men generally of little or no education, who have risen to that station by a superior attention to their art, in which they have been incessantly occupied from the early age of five or six years. A century ago among the miners of Cornwall, whatever was not tin was heedlessly thrown aside; and within that period, on the discovery of copper ore beneath the tin, it was no uncommon observation, that the 'ore came in and spoilt it.' It is an undoubted fact that many roads in the county were mended with copper ore. The discovery of the native silver in Herland mine would have passed unnoticed, but for the vibrations of some capillary portions having accidentally attracted the notice of a workman; and it is confidently believed that much of that precious metal has been thrown away on the neglected heaps of that mine. Even now, whatever is not manifestly tin or copper, or is not suspected of yielding those metals, is paid little attention to; and the practical miner sees no value in the inquiry into the run of veins, the nature of the country they traverse, their contents, or uniformity, further than relates in his own estimation to the immediate benefit of his occupation; and he smiles at the nice discriminations of the mineralogist. If an inquiry into the phenomena of veins be made of him, he refers, by one short cut, to the universal deluge.

The total ignorance of almost every thing relating to the sciences of geology and mineralogy, and above all of chemistry, in the conductors of mines, and their agents, is not only matter of regret, but it can scarcely be doubted, is also the cause of much loss to the adventurers in mines, to the lords of the soil, and to the buyers of the ore. If a spirit of inquiry had existed, which some knowledge of these sciences could not have failed to produce, much cobalt would not have been thrown away on the heaps of Dolcoath and some other mines, nor would bismuth in Huel Sparnon have been mistaken for cobalt, nor would the roads have been mended with copper ore, nor would the ponderous ore, which contained silver in Herland mine, have been left to the chance that discovered its value, nor would many miners, in opposition to all the known principles and properties of mineral bodies, believe, even to this day, in the regeneration of metals.* While in France, and in Germany, there are national institutions for the education of those intended to conduct the working of mines, in the three important branches of science before alluded to, and which are so intimately connected with their occupation, in this country all is left to accident, and the rich gifts which nature has bestowed upon us, are consequently often neglected, or lavishly thrown away.

The ores of copper, as sold at the mine, though some of them are richer, do not in most instances contain more than one-twelfth of copper, frequently not one-fifteenth, some of them not one-twentieth. The accompanying substances are a heterogeneous mixture of earths and metals, amongst which arseniates of various kinds often bear a considerable proportion. It needs not to be insisted upon that much attention ought to be given to free copper from arsenic, which is so very liable to render it brittle. When a pound or two of the ore is given to the sample-trier, as a fair sample of 50 or 100 tons, his report is but too often grounded on the weight of the *prill* he has obtained from a given quantity of the ore, without reference to the substances with which it may be alloyed, which indeed his skill does not enable him to detect. When the ore is taken from the mine, it is for the most part deposited, not that of each mine separately, but mixed with that of many others, without regard to the great difference that must of course exist in the ore of veins, circumstanced so variously as are those of Cornwall.* And strange as it may seem, it is notwithstanding true, that even the interest of the buyer seldom tempts him to swerve from the hacknied practice of his predecessors, in making purchases to an enormous amount on the reports of those whose skill only extends to the extracting of the heaviest prill, without possessing a knowledge of chemistry sufficient to enable them to discover of what it is compounded.

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* "Whether tin doth grow again, and fill up places which have been formerly wrought away, or whether it only separateth itself from the consumed offal, hath been much controverted, and is not to this day decided." And "whether—dead lodes—that have not one grain of tin in them—may not hereafter be impregnated, matured, and prove a future supply to the country, when the present lodes are exhausted, I think well deserves our highest consideration." Notes to Carew's Survey of Cornwall, edit. 1811, by Tonkin, edited by Lord de Dunstanville. It must be confessed that these inquiries still prevail amongst practical miners.

Enough has been said in the preceding pages of the uncertainties attending the pursuit of the miner, to amount to evidence that skill and ingenuity are often exerted in vain:—all they can do is to determine on, and put in practice the speediest and most effectual methods of ascertaining the value of a vein, at the least expense. When assisted by the best experience, they are utterly unable to form a conjecture, grounded on reasonable certainty, that the great expenses attending the trial of a vein will be repaid. If indeed the reverse of this were the case, there would not be, as there now are, so many skilful captains of mines who have lost money by their adventures. If experience avails so little, theory cannot be expected to avail any thing; and it may fairly be doubted whether all that science could bestow on the practical miner, would, in this branch of his occupation, be found to be of the slightest advantage.

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* In reply to this observation, it has been said that the ores of some mines are found to smelt more easily when mingled with those of certain other mines, than alone. This will not perhaps be doubted. All that is now contended against is, the common practice of mixing indiscriminately ores of copper of any, or rather of every description.

The habits of the miner are those of industry and perseverance, which often tempt him to exploits that excite astonishment at his venturous hardihood. The very idea of a descent beneath the surface of the earth has something in it of the terrible, at which those shudder who are unacquainted with practical mining. But such is the force of habit, that rarely does any other employment tempt a miner to forsake his own. The occasional perils of his occupation are scarcely noticed, or if noticed are soon forgotten. He walks, often in the middle of the night, and in all weathers, two or three or more miles to the mine, undresses, and puts on his underground clothes, and with his tools slung over his shoulder, descends by ladders a depth of 1000 or 1200 feet, assisted by the light of a small candle, and works in the bottom of the mine six or eight hours, amidst the noise of the working of the pumps in drawing the water, with as much alacrity, and with as little sense of danger, as he would feel amidst his ordinary occupations above ground. We should be inclined to feel pity for the wretch who, as an atonement for his crimes, should be compelled to undergo what the Cornish miner voluntarily undertakes for a small pittance, and that even of an uncertain amount. 'The mine of Huel Cock, in the parish of St. Just, is wrought eighty fathoms in length under the sea, below low water mark; and the sea in some places is but three fathoms over the back of the workings, insomuch that the tinners underneath hear the break, flux, ebb, and reflux of every wave, which, upon the beach overhead, may be said to have had the run of the Atlantic ocean for many hundred leagues; and consequently are amazingly powerful and boisterous. They also hear the rumbling noise of every nodule and fragment of rock, which are continually rolling upon the submarine stratum; which altogether make a kind of thundering roar that would surprise and fearfully engage the attention of the curious stranger. Add to this, that several parts of the load which were richer than others, have been very indiscreetly hulked and worked within four feet of the sea; whereby in violent stormy weather the noise overhead has been so tremendous that the workmen have many times deserted their labour, under the greatest fear lest the sea might break in upon them.'

The account of Huel Cock above cited, is extracted from the Mineralogia Cornubiensis of Pryce, page 21. I have made some use of the mining information contained in that work, which, though it is often confused, and sometimes scarcely intelligible, is, apart from its reasonings and its philosophy, a valuable production. I have not thought it necessary to acknowledge my obligations to it in every particular instance; nor, on the other hand, have I been willing to quote its authority, without verifying it by an appeal to some of my numerous friends among practical miners.

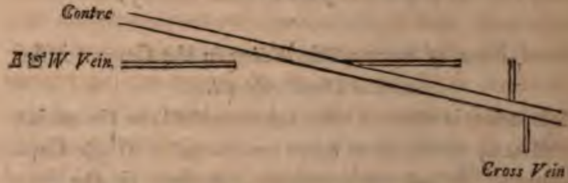
As an appendix, it seemed to me that some account of the veins of certain mines, remarkable either for their peculiarities or some striking geological fact, might therefore be an acceptable addition to the geologist, as well as in corroboration of what has preceded. I have however to express my regret that these relations are imperfect, inasmuch as little is said on the subject of the *countries* in which these mines lie. For as the information on that head could only be obtained from the practical miner; and as he notices the country merely as respects the ease or difficulty with which his operations are carried forward, or at most no further than regards his three grand distinctions of grouan, killas, and elvan, little or nothing satisfactory could be obtained, on that important part of their history.

Ground Plan of some of the Veins in the Copper Mine called Huel Alfred.

This mine is situated on a schistose hill, in the parish of Phillack, about three miles south-east of Hayle Copper-house. It had been worked previously to the year 1800, but was abandoned principally on account of the surrounding country having fallen in, and filled up or destroyed the only shaft that had been sunk. This circumstance was, most probably, the cause to which the successful working of the mine may be attributed. For, being compelled to sink another shaft, it so happened that the chosen spot was immediately above a vast body of ore which has never failed since its discovery. But as copper ore had been left at the bottom of the shaft that had fallen in, a level was carried to that place; it was however found to be a mere bunch, which circumstance, it is most probable would have deterred the miner from an effectual search after the great riches pitched upon by sinking the new shaft about 100 fathoms west of the former one.

Notwithstanding Huel Alfred is one of the richest and most profitable copper mines that Cornwall has now to boast of, a particular description of some of its veins would not have been now attempted, but for some circumstances worthy of particular notice, viz. that one of its veins is of that description termed a contre, remarkable for its magnitude and riches as well as its direction, and on account of the effects produced by its traversing an east to west vein, and a north and south vein, or cross course.

Ground Plan.



Both the shafts above alluded to were sunk on the contre, the direction of which is 28 degrees south of east and north of west. It varies from 9 to 24 feet in width, its underlie is two feet in a fathom to the east of north. At a small depth this bore the appellation of a 'Flucany Load.' Flucan prevailed very much between the depth of 50 and 70 fathoms from the surface, and burst out occasionally with such vehemence as to drive away the workmen. Captain Samuel Grose, an intelligent captain of the mine, informed me that he was once carried away seven fathoms by its sudden irruption. But little flucan was seen at much greater depth. Beneath it and above the copper, very great abundance of sulphuret and carbonate of lead occurred, together with iron pyrites, blende and quartz. The greatest extent to which the contre has been worked is 160 fathoms from its junction with the east and west vein towards the south east; 90 fathoms of which, at about 130 from the surface, are good ore. The only place at which the contre was rich when in contact with the east and west vein, was at about 117 fathoms from the surface. North-west of its junction with that vein, the contre was small, and for more than 100 fathoms in depth consisted of strings of flucan, but at about the depth of 120 fathoms it enlarged to twelve feet in width and yielded some ore, mingled with fluor, blende, and iron pyrites in abundance; at 130 fathoms in depth, it was poor for 20 fathoms from its junction with the east and west vein, and then succeeded 40 fathoms of what the miner terms *orey ground.*

It seems to be the opinion of a very intelligent and experienced miner, Captain John Davey, who was a captain in Herland mine, and is now the managing captain of Huel Alfred, that the contre of the latter is a continuation of that of Herland.

The east and west, or regular metalliferous vein averages about 2½ feet in width, and runs 10 degrees south of east and north of west: it underlies 2½ feet in a fathom towards the north. The ore was about 110 fathoms in length east of its junction with the contre, but the east and west vein is poor every where when in contact with it, except at the only place at which also the contre is rich, viz. at about 117 fathoms from the surface.

West of the contre, the east and west vein is lost for nearly 30 fathoms; and when discovered again, it varies from 18 inches to 4 feet in width, and its load was found chiefly to consist of flucan with some blende.

The ore of the contre is yellow and occasionally compact, but it is for the most part approaching to black externally; and where richest, is loosely intermingled with small portions of quartz, blende, and iron pyrites, which prevailed very much near the surface.

The ore of the regular vein east of the junction with the contre is also yellow, and for the most part hard; but it is occasionally loose.

The common effect of a cross or north and south vein is, that it passes through the east and west or metalliferous vein, and mostly alters its course. A cross vein occurs in Huel Alfred; its effect on the east and west vein is not yet known, but a rare exception to the general rule of north and south veins traversing metalliferous veins is here exhibited; for the load of the contre, which, as has been said, is rich in copper, not only passes through the north and south vein, but also heaves it out of its regular direction four fathoms. This is the only instance of the kind that has come to my knowledge.

The run of the cross vein is direct north and south; it underlies west about one foot in a fathom; is nine feet wide, and close to the contre (where only it has been seen) is chiefly filled with quartz, accompanied by blende and carbonate of lead in very small quantities, but in it there is no flucan; at and below forty fathoms from the surface, the quartz assumed the form of a fine sand, and the water from the cross vein was so powerful as to wash the sand 90 fathoms into the contre, so as occasionally to choak the pumps. It should be remarked that no ore was seen in the latter, while passing through the cross vein for more than 100 fathoms from the surface.

About 45,000 tons of copper ore, the produce of Huel Alfred, have been sold since the beginning of 1801, for the sum of about £350,000. The number of men, women, and children, employed underground and on the surface, amounts nearly to 1500. There are three large steam engines for drawing the water, and two steam whims for drawing the ore, now on the mine, (1812). The monthly expenses for labour, coals, ropes, timber, &c. amounts now to about £5300. The profit hitherto divided amongst the adventurers amounts to about £120,000.

Some other accounts of remarkable circumstances relating to the veins of other mines were annexed to this paper, which are here omitted on account of their demanding plates for their illustration. They may be consulted in the second volume of the Transactions of the Geological Society.

Of the SECTIONS, Plate 2.

The principal object in noticing the Sections, in this place, is to refer the reader immediately to the pages in which their more important features are treated of. It may however be requisite to add a few short and general remarks.

Fig. 1.

This is the only natural section of the four. It is a representation of the cliffs of the north-western coast of the Isle of Wight.

In the alluvium of Headen hill, forming the northernmost part of that line of coast, nothing worthy of particular notice has been observed: but some account of the remarkable and alternating deposites by salt and fresh water, on which it lies, will be found under the head *Freshwater formations*, (§ 15, and seq.)

To these the London Clay succeeds, on the south: (§ 28.) In all other places in which this clay has been observed, its position is flat, or nearly so. The same observation is applicable to the many colour and *vertical* strata of sands and clays, extending 1131 feet on the south of the London clay, and which belong to the *Plastic Clay formation* (§ 33), as well as to the vertical chalk, succeeding them on the south. Some observations on the position of these strata in this place, will be found in § 48.

Fig. 2.

The line of this section may readily be traced upon the little map opposite the title-page. It must be confessed that it is in some sort theoretical, for it is impossible with certainty in all cases to assure ourselves that the strata which rise to the surface, or are so near it as only to be covered by the alluvial soil, do actually pass away beneath it with regularity to any very considerable depth. One circumstance is particularly worthy of notice. It has been discovered, wherever the strata have been pierced, that the inclination of the newest deposites differs greatly from that of those which are esteemed to be of the oldest formation:—that the former lie nearly flat, while the latter pass away beneath the surface at a considerable angle with the horizon. The chalk, for instance, does not often exceed the angle of 15 degrees, and its strata near Dover, which are remarkably regular, are so nearly horizontal, as to differ from that position less than one degree. While, on the other hand, the strata of clay-slate beyond Exeter on the west, incline at an angle of at least 70 degrees.

Some remarks on this section will be found in the Introduction, page 12.

Fig. 3.

The line of the foregoing Section is about north-east and south-west; the line of this, is more nearly east and west, and on consulting the map, it will be seen that it crosses the former.

The chief object in giving this section, is to shew the interesting fact, that a large proportion of the counties of Kent and Surrey, though surrounded by the chalk do not rest upon it, but consist of a sand which is similar in so many respects to that on which Devizes stands, as that their identity is determinate. Some observations on this subject will be found in § 61.

The authority for placing the Old red sandstone, as the supporting rock of the mountain limestone near Bristol, will be found in § 151.

Fig. 4.

This section relates primarily to objects of more than common interest, namely, the most important Coal formations of our country. The line of section may readily be traced in the little map. A long detail of that on the eastern coast, will be found under the head *Coal* (§ 94 & seq.), including the substances with which the beds of coal are interstratified, as well as those on which the whole formation lies; although the latter are considered to belong to the Mountain Limestone formation (§ 97, note); but it seemed to promise some advantage not to separate them (§ 102). Beneath the limestone, and between it and greywacké, lies the old red sandstone (§ 154.) The greywacké abuts against greenstone (§ 166), on which repose broken, or irregularly stratified, beds of limestone and coal. To these succeeds the red marle, or new red sandstone (§ 76), in nearly horizontal layers, reposing, on the west, on mountain limestone. This limestone (see Map) passes northwards round the slaty mountains of Cumberland, of which Skiddaw is the highest, in a semicircular form, and underlies the extensive Coal deposite in the neighbourhood of Whitehaven.

It is remarkable that the Coal is covered, both on the eastern side of the kingdom (§ 87) and on the western (89), in part by the magnesian limestone; tending to shew that the true geological position of the independent coal-formations of England is between the magnesian limestone and mountain limestone. This section likewise shews that the position of the red marle is above the magnesian limestone, which has been proved near St. Bees' head, not far from Whitehaven. (§ 76).

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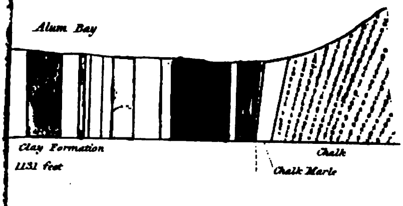

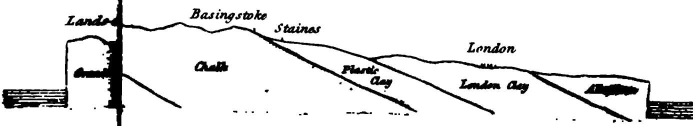

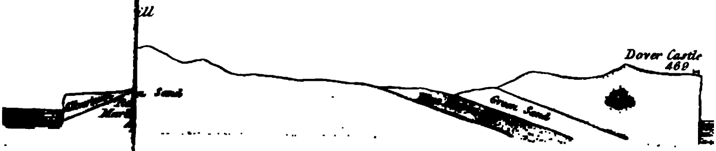

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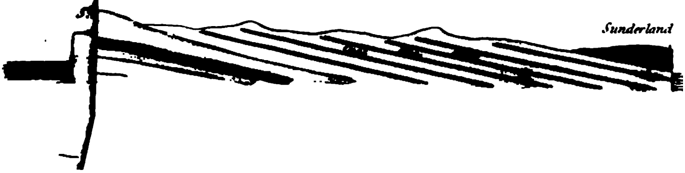

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" ORDER OF SUPERPOSITION," &c. at the end of the Volume.

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